Water Power

INTERNATIONAL DEVELOPMENT OF HYDRO-ELECTRIC POWER

PRICE 2/6 NOVEMBER 1952

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HYDRO-ELECTRIC POWER IN INDIA

The Madras Government Irrigation and Power scheme depends on hydro-electric stations such as Mettur Dam shown. Metrovick generators, transformers, switchgear and protective apparatus, etc., are used extensively on the system. Mettur station contains 4 Metrovick 12,500 kVA generators.

METROPOLITAN-VICKERS ELECTRICAL CO. LTD
MANCHESTER 17, ENGLAND
Member of the A.E.I. group of companies
AX/A002

The name REYROLLE means very different things to different people. It means the company who pioneered the metalclad compound filled drawout construction . . . who are building one of the largest short circuit testing stations . . . who have an excellent student training scheme . . . who have supplied switchgear for power stations and substations throughout the world. To some people, since like everyone else we have our critics, it means the company who makes too many horizontal drawout designs or not enough, who concentrate on this to the exclusion of that . . .

But first, last and all the time, the name *Reyrolle* means specialists in switchgear. By way of illustration, in various departments throughout our organisation there are over 40 people who have each worked at Reyrolle for over 40 years. They have never, except during times of national emergency, worked on anything other than switchgear.

Our primary concern is designing and producing switchgear, so if you have any transmission or control problems, why not talk to us.

If you want to talk switchgear . . . talk to Reyrolle

A. REYROLLE & COMPANY LIMITED · HEBBURN · CO. DURHAM
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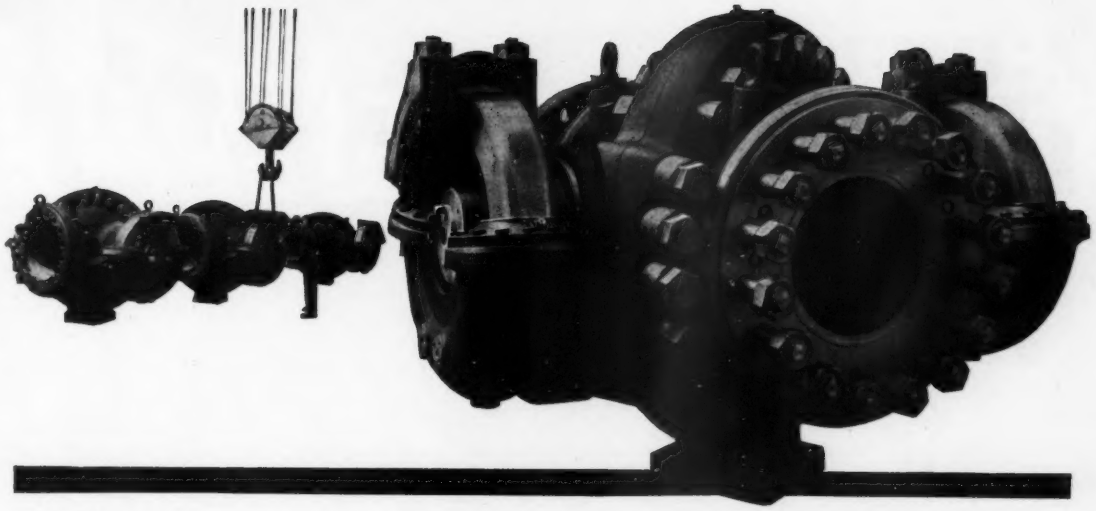

Rotary Slide Valve
with hydraulic rotary-piston drive
and dual sealing. Diameter of bore 600 mm.
Working pressure 150 atm.,
Testing pressure 270 atm.,
Face-to-face length 2600 mm.
Height 2100 mm., width 3000 mm.

Equipment for Hydro-Electric Power Stations

Complete barrage installations; hoisting equipment and cranes; sluices and sluice-valves; grid clearing machines; shut-off valves for high-pressure conduits; high-pressure conduit fittings; circular slide valves; rotary slide valves with hydraulic rotary-piston drive; shut-off valves for emergency and bottom outlets; piping systems for oil and cooling-water plant; funiculars and aerial cableways for passenger and goods transport; building machinery for dam-building work.

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Louis de Roll Iron Works Ltd., Works at Gerlafingen (Head Office),
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We specialise in manufacturing Power Transformers for Generation, Transmission and Distribution. All YORKSHIRE Transformers are designed, constructed and tested to the corresponding British Standard Specification.
We make Transformers to suit all requirements up to 60,000 k.V.A. - 132,000 volts.

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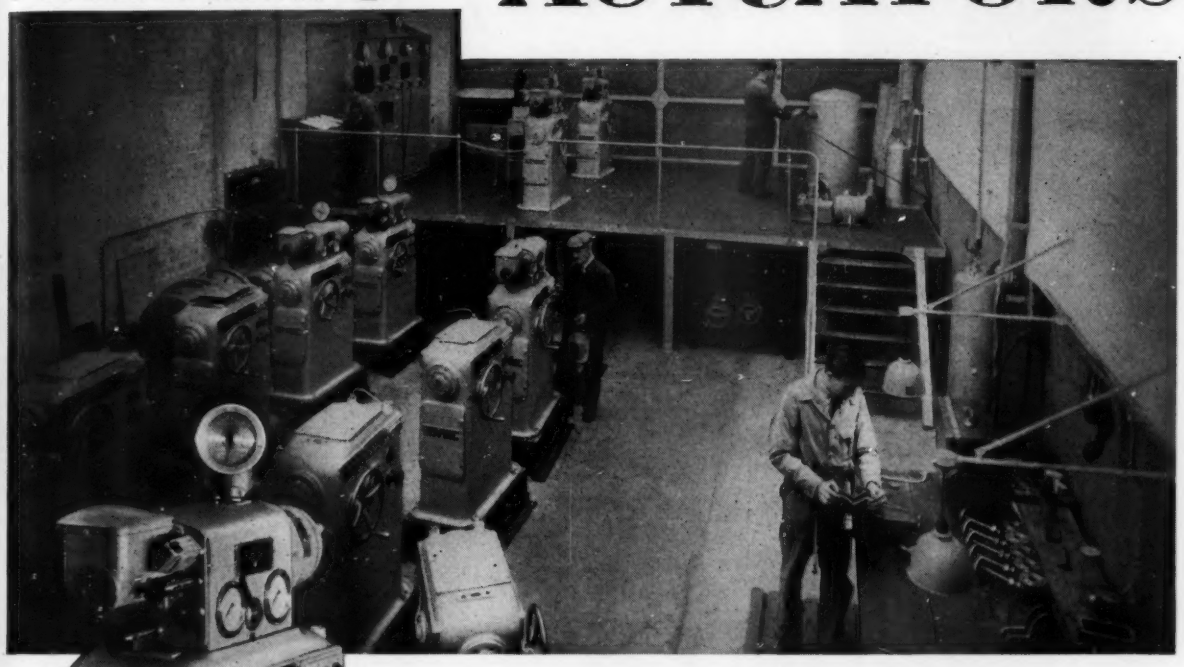
YORKSHIRE ELECTRIC TRANSFORMER Co LTD DEWSBURY · ENGLAND

Boving
& COMPANY LIMITED

WATER TURBINE ACTUATORS



This is the most modern type of Boving Actuator — the F.10 and it is here seen both in process of assembly, and undergoing test at the works of John Brown & Co. Ltd. at Clydebank.

These Actuators contain the speed-responsive element of the governing system of large water turbines. They are highly sensitive and embody every modern feature to enable them to meet the onerous governing requirements of a large turbine.

In normal practice Actuators are arranged for remote control and the F.10 is particularly suitable for fully automatic plants.

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BC.6

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For electricity supplies and all industrial undertakings we supply:

Equipment for telephony, tele-control, tele-metering, and tele-regulation over pilot or low- and high-voltage lines.

Carrier telephony and tele-metering channels over high-voltage power lines with h.f. wave trap, coupling capacitor, protective gear, line matching unit, and carrier apparatus cabinet.

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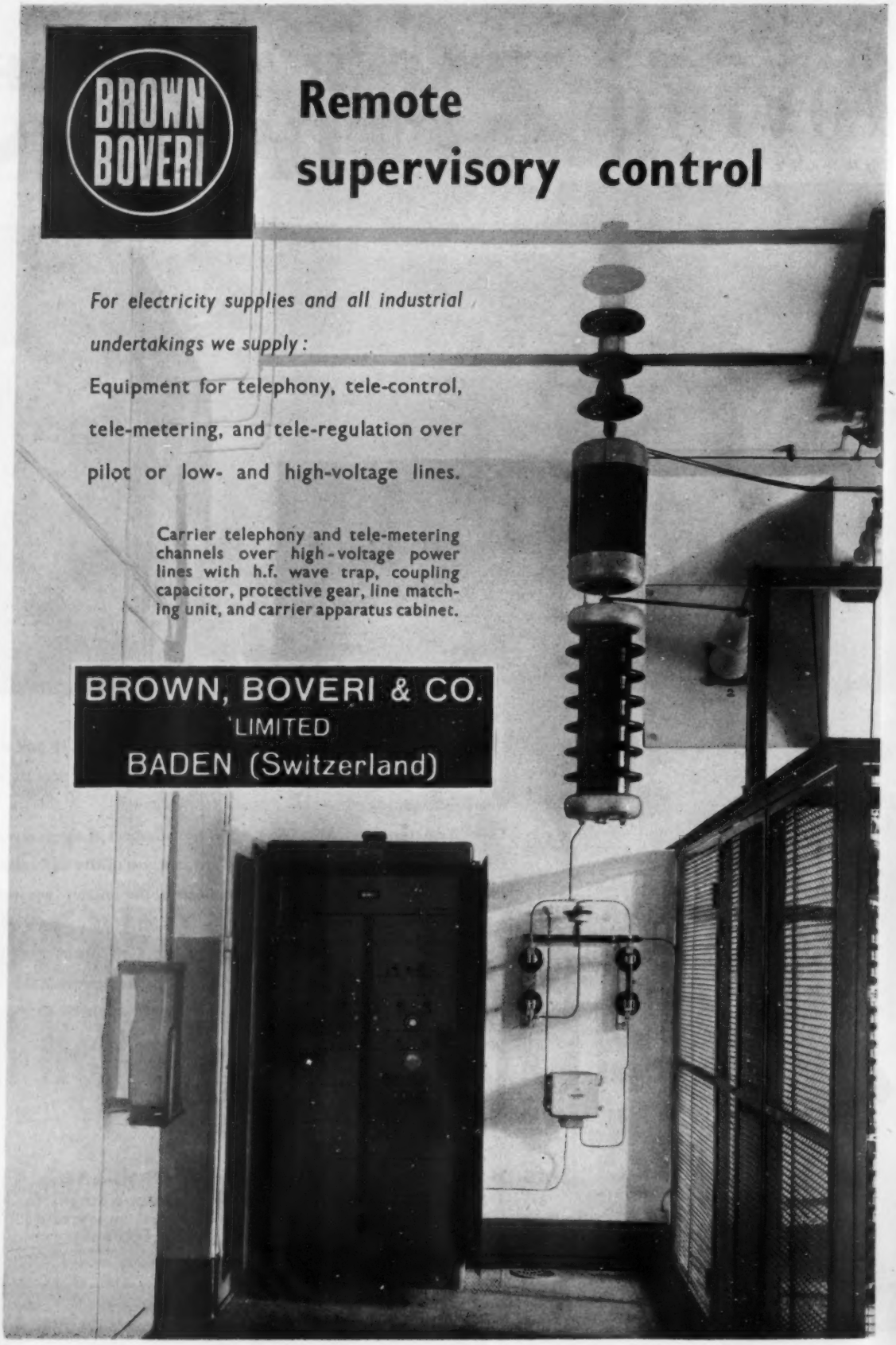

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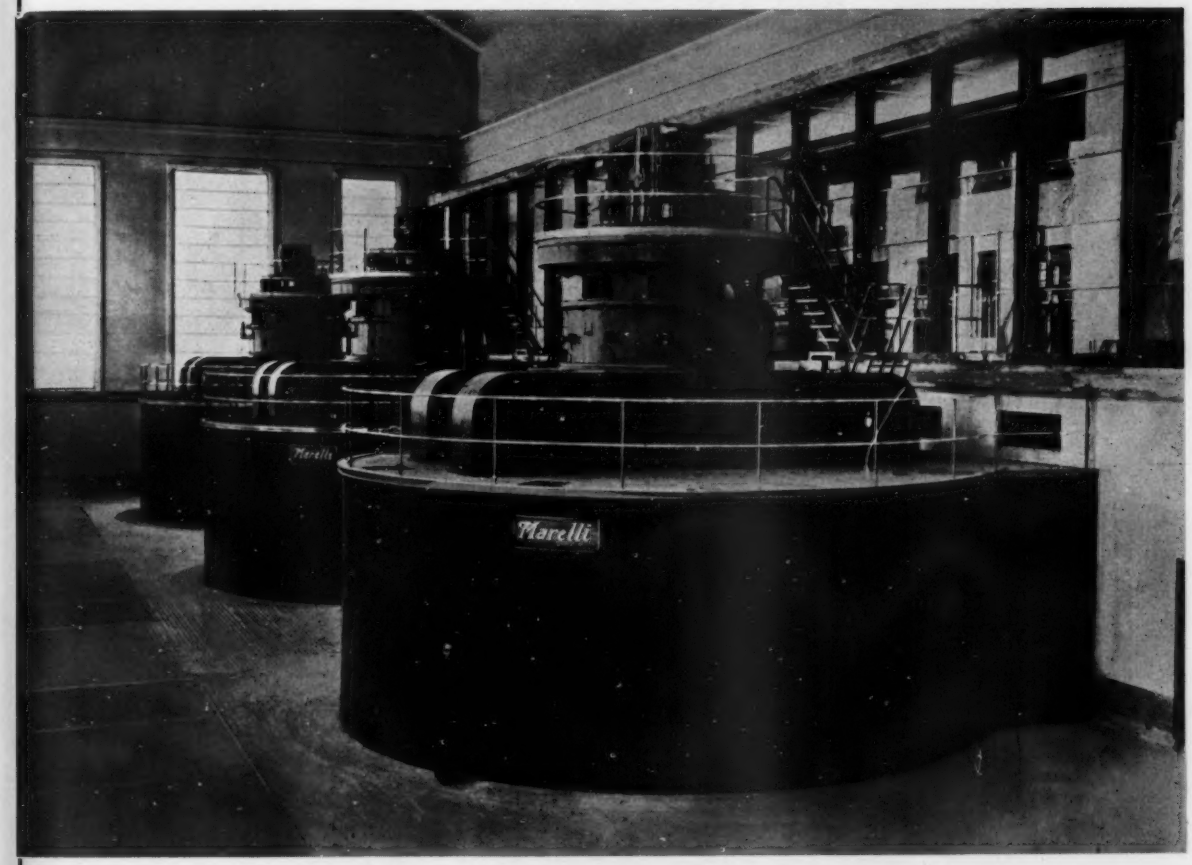
FOR OVER 30 YEARS MARELLI HAVE MANUFACTURED GENERATORS AND TRANSFORMERS FOR HYDRO-ELECTRIC POWER PLANTS

Marelli also specialise in the manufacture of electrical equipment for steel works, ship propulsion, traction - Land drainage and Irrigation Plants - Ventilation Plants



THREE 60,000 K.V.A. - 10,000 VOLTS - 428 R.P.M.
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installed at the Soverzene Underground Generating Station
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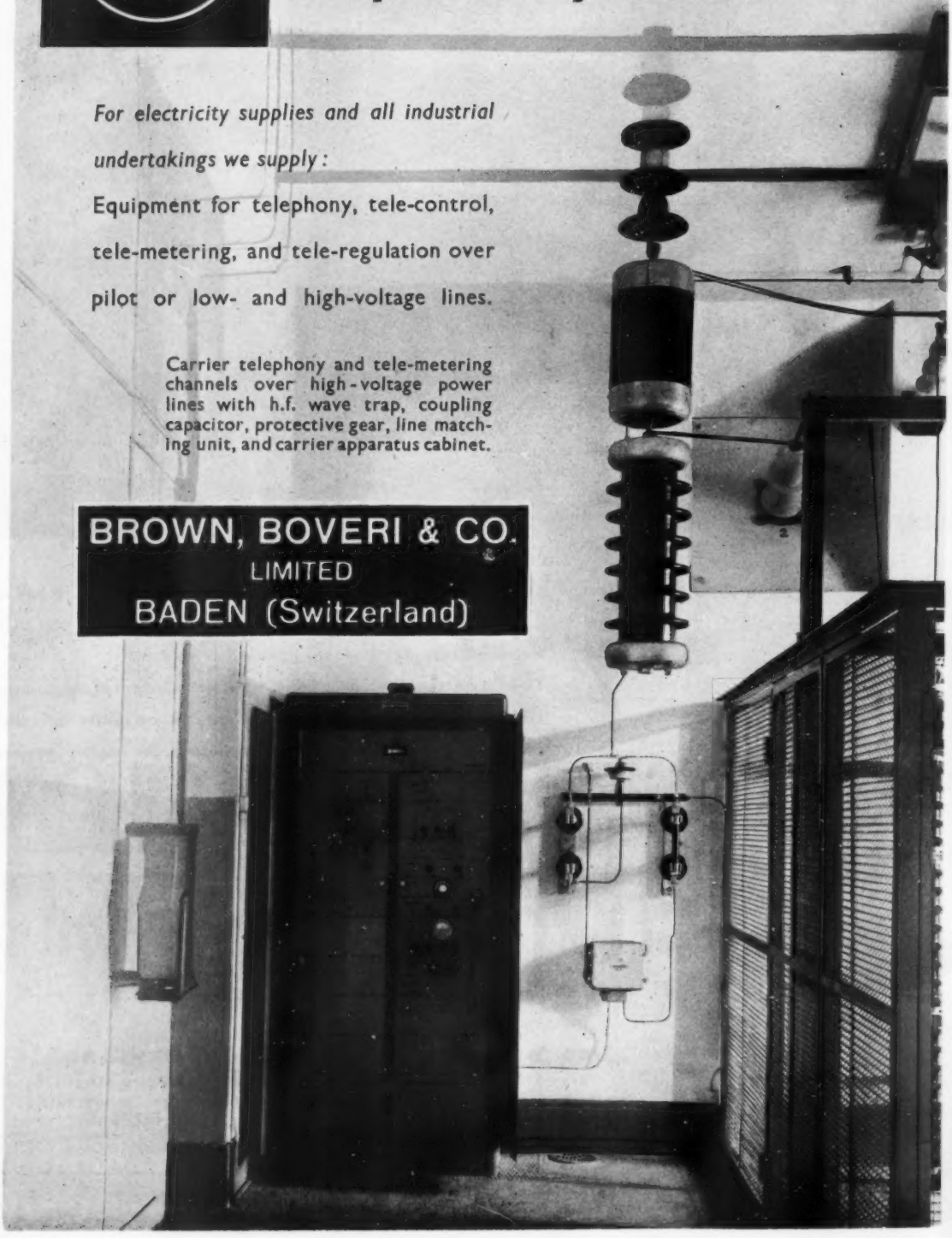

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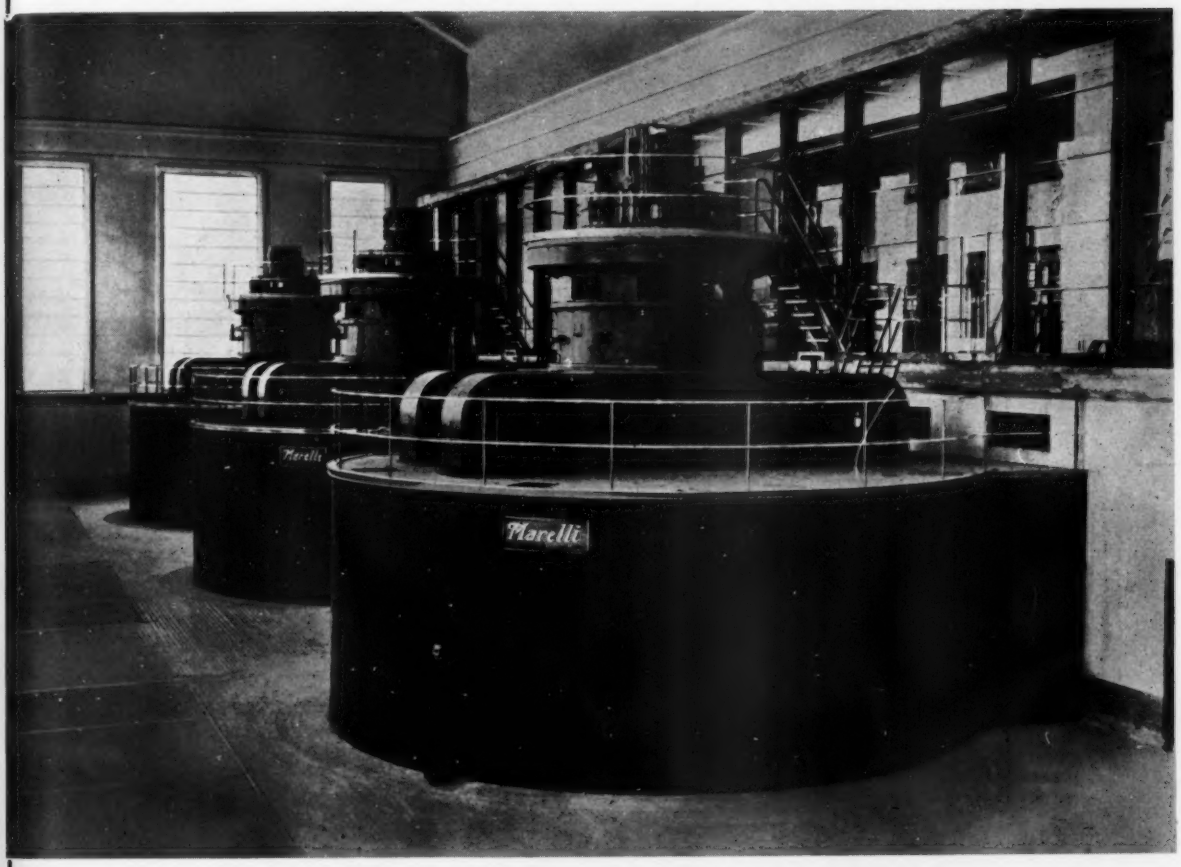

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Night and day in all weathers Henderson Aerial Cableways consistently maintain scheduled construction programmes. The speed, economy and efficiency of Henderson Cableways are essential factors in large building, constructional and hydro-electric undertakings. Henderson Cableways were used for the construction of the Dams at Loch Sloy and Glen Shira, North Scotland, Hydro-Electric Board, and various other home and overseas undertakings.

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SENSING the potentialities of water as a source of power, S. Morgan Smith, our founder, applied his energies to its utilization.

His pioneering effort in the development of one of the early water turbines to be built in the United States ended in success. Shrewd men adopted the water turbine as a source of power in ever greater numbers. But S. Morgan Smith's pioneering spirit continued—a spirit still manifesting itself in our endless research and experimentation—factors in the future development of POWER!

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POWER *by* SMITH

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THE NEW CP 59 ROCK DRILL WITH 2¼" DIA. FEEDLEG. . .

AND "SECO" TUNGSTEN CARBIDE TIPPED SWEDISH DRILL STEELS

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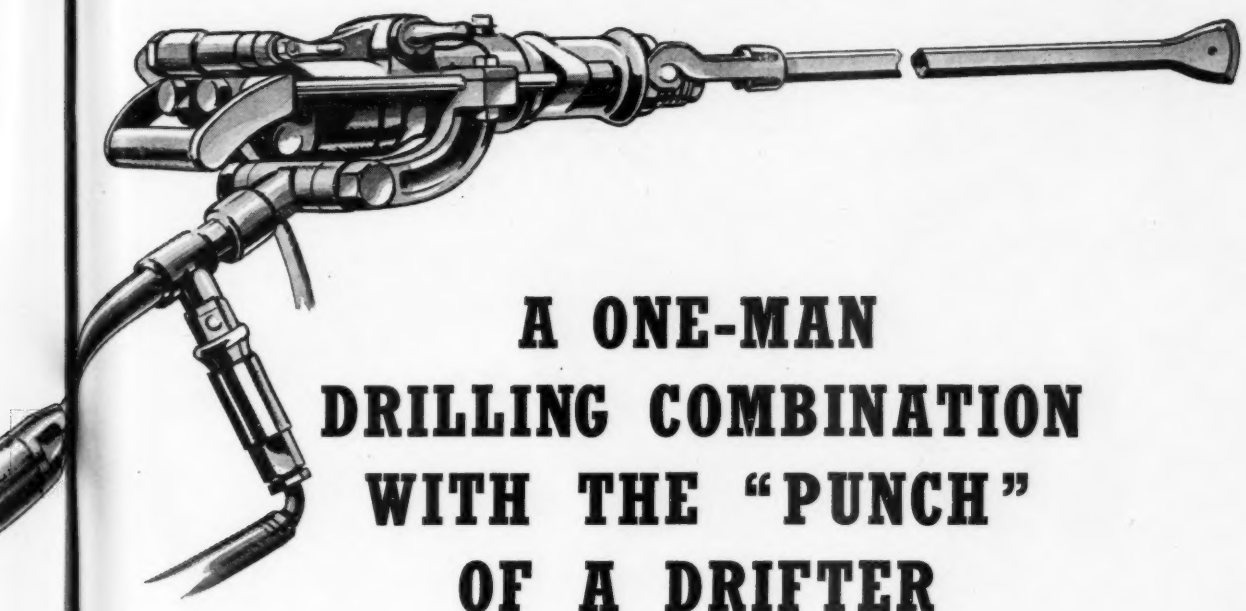

A ONE-MAN DRILLING COMBINATION WITH THE "PUNCH" OF A DRIFTER

The new hard-hitting CP-59 Rock Drill is now teamed with a tougher, more powerful "Feedleg" having a $2\frac{1}{4}$" diameter piston for ample "backing up". In this new CP combination, utilizing the world famed SECO Tungsten Carbide tipped Swedish steels, the ultimate aim has been reached in tunnel driving equipment . . . a light one-man rig with the "punch" of a drifter.

The CP-59 Rock Drill in the 55 lb. class is itself an outstanding machine, with high piston speed, automatic lubrication and many new features of design. Couple this fast drilling tool to the new CP "Feedleg", with its infinitely variable throttle, and you have the most powerful, most perfectly controlled equipment of matched performance yet produced for hard rock tunnelling.

Where tough conditions in tunnels, in quarries, in mines and on site clearance call for equipment with more power than the lighter machines, here is the answer—

the CP-59 with $2\frac{1}{4}$" diameter "Feedleg".

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The fastest, most economical method of placing BULK CONCRETE giving

Blaw Knox concrete pipe lines on the construction of the Royal Festival Hall—Main Contractors—Messrs. Holland & Hannen and Cubitts Ltd.

BETTER
placing of high quality concrete at the lowest cost per cubic yard.

BETTER
placing on awkward sites—uphill, downhill and underwater . . . traversing highways and railway tunnels without obstructing traffic.

BETTER
placing without rehandling problems . . . no chutes, hoists, towers, buckets, cranes, etc.

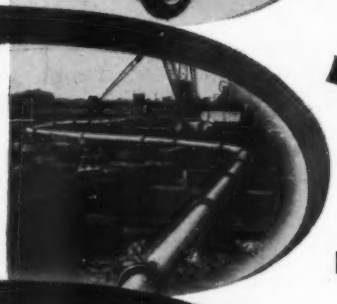
BETTER
utilisation of man-power—with one man more concrete can be placed than by a whole team using old fashioned methods.

PUMP IT

Basic component of the system is the BLAW KNOX portable, two speed, heavy duty, single acting horizontal piston pump. Capacity 15-20 cubic yards of concrete per hour.

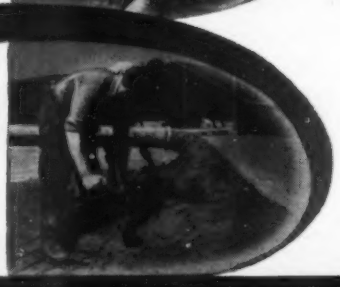
PIPE IT

BLAW KNOX Concrete Pipelines comprise 6" steel pipes in various lengths up to 10' and simple, quick-acting couplings with rubber seatings for fast assembly and dismantling. During pumping the pipeline is completely filled, concrete moving through in synchronous impulses in an excellent state of uniformity.



PLACE IT

Concrete is poured straight into the forms, exactly where it is needed.



Blaw Knox engineers will be glad to advise on the application of the Concrete Pump to specific jobs.

BLAW KNOX

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BLAW KNOX *Concrete by Pipeline*

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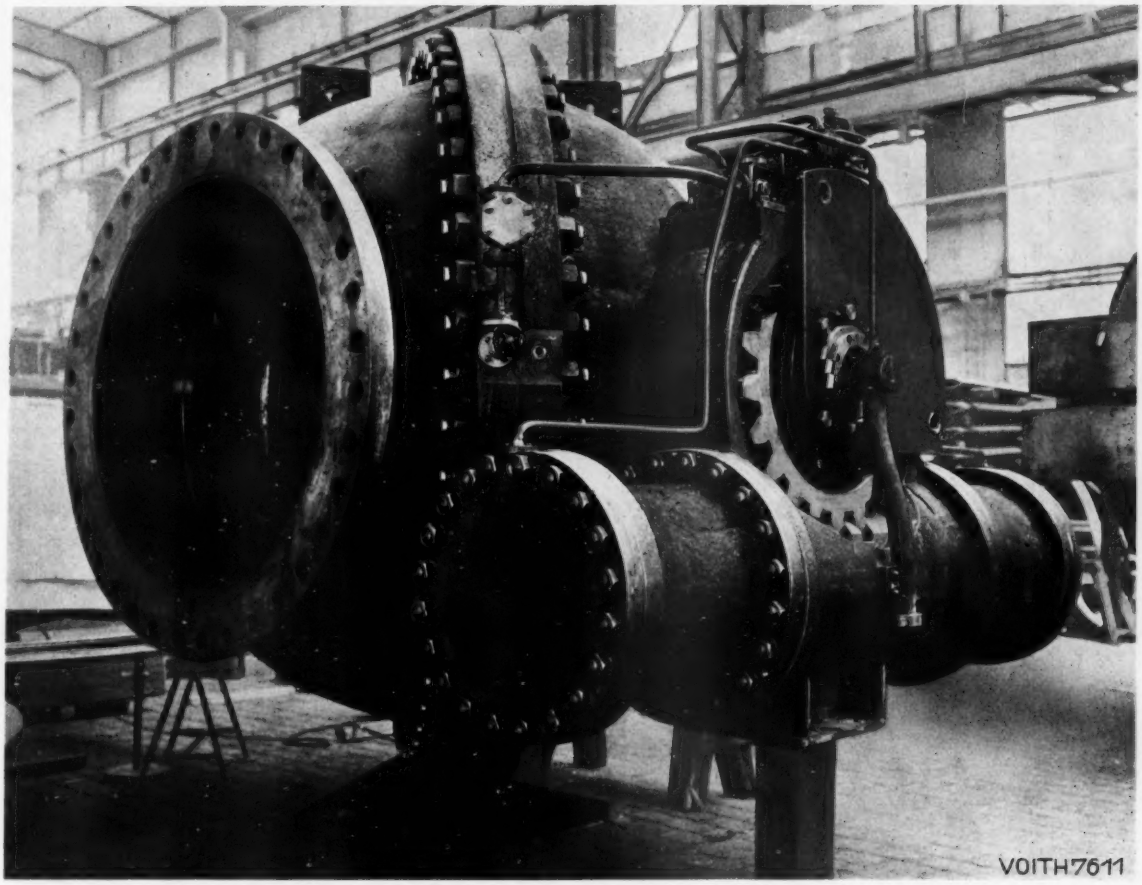
Telephone: Kensington 5151 **Telegrams: Blawnox, Southkens, London**

Voith Penstock Shut-Off Valves



Workshop assembly of a spherical valve, inside diameter 1500 mm., with hydraulic drive. The casing of the spherical valve is diagonally split

We have supplied :

Spherical Valves inside diameters up to 2,200 mm., maximum water pressures up to 1,010 m. water column.

Needle Valves inside diameters up to 2,800 mm., maximum water pressures up to 600 m. water column.

Butterfly Valves inside diameters up to 5,300 mm. at 70 m. water column.

J.M. Voith G.m.b.H., Engineering Works, Heidenheim (Brenz)
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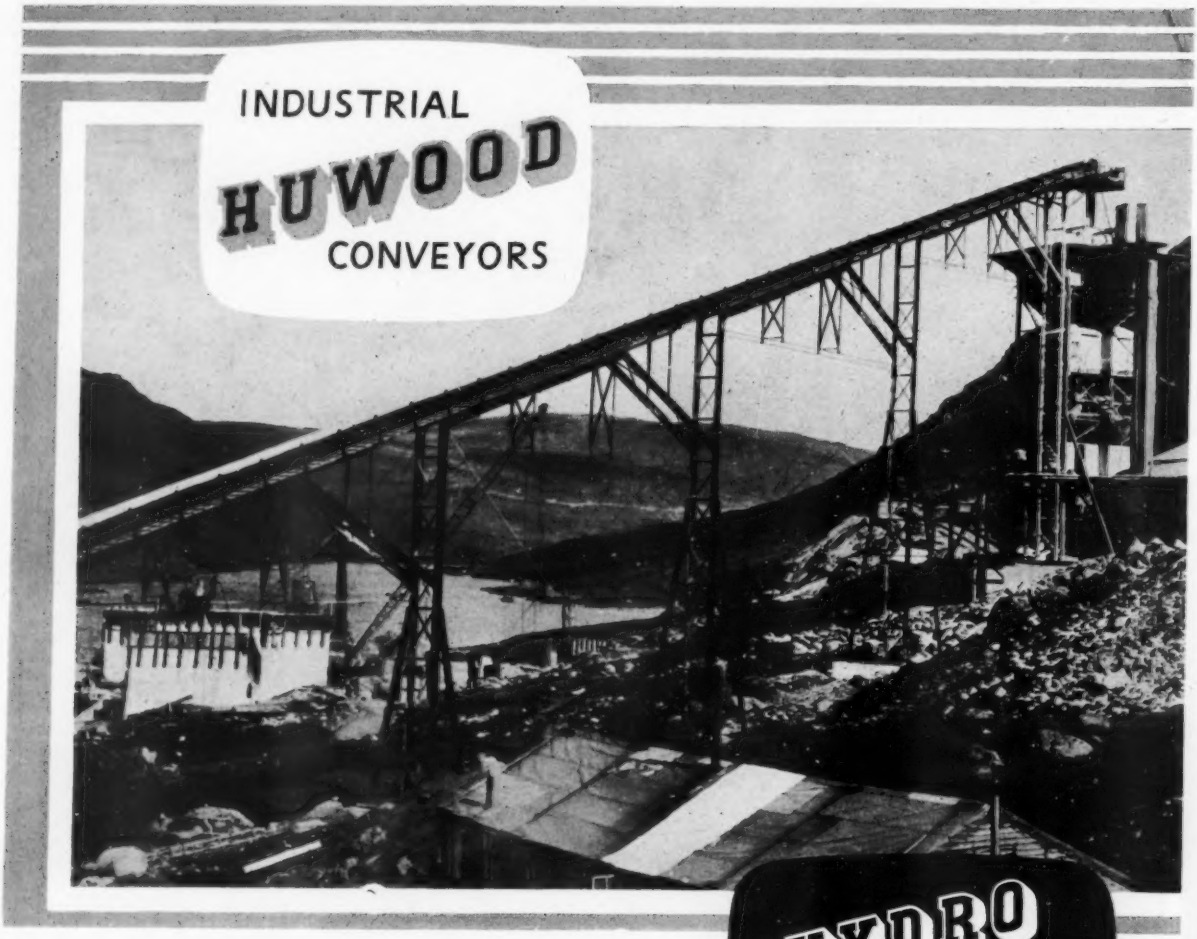

HYDRO ELECTRIC

SCOTLAND · TUMMEL GARRY · LOCH SLOY
ERROCHTY DAM

AFRICA · OWEN FALLS · UGANDA

INDIA · HIRAKUD DAM PROJECT

HUGH WOOD & CO. LTD.

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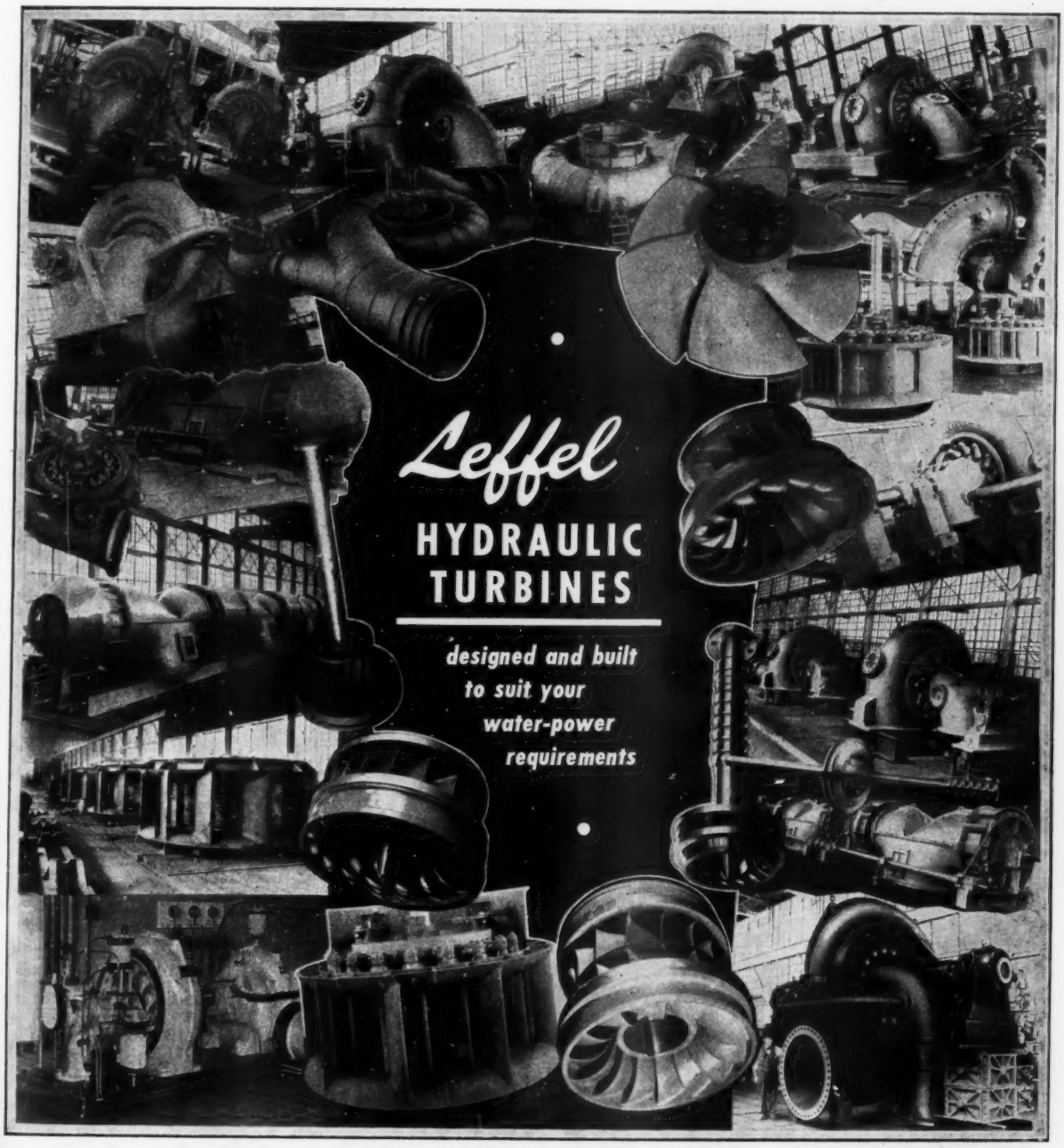
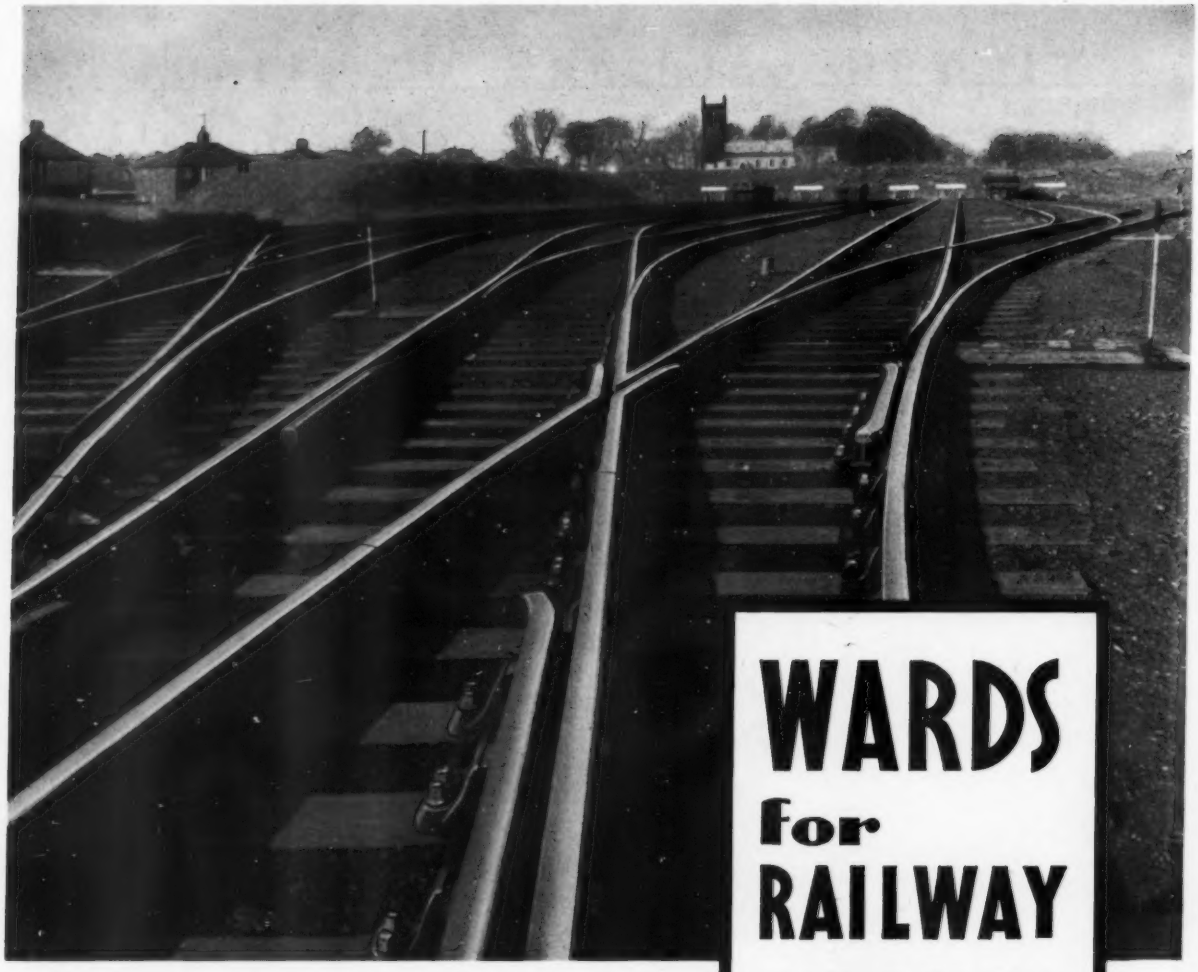


FOUNDED IN 1862

THE JAMES LEFFEL & CO.

DEPARTMENT W • SPRINGFIELD, OHIO, U. S. A.

MORE EFFICIENT HYDRAULIC POWER FOR 90 YEARS



WARDS for RAILWAY SIDINGS

IN the planning and construction of railway sidings, Wards offer a high degree of technical skill and experience. Wards have been building sidings for nearly half a century and thus bring to the subject an extensive knowledge of a variety of operating conditions. Similarly, in the supply of railway equipment generally, Ward's Rail Department service covers new and re-usable rails of all normal sections, as well as switches, crossings, turnouts, buffer stops, etc. Associated supplies include colliery arches, pit props, roofing bars, floor plates, and, of course, all manner of track accessories and tools. In short, Wards have a comprehensive service on every aspect of railway siding, planning, construction and maintenance for industrial operation.

The layout illustrated above shows a ladder of sidings at the Primrose Hill Unit of the National Coal Board, by whose courtesy the photograph is reproduced.

ANOTHER ASPECT OF TWW SERVICE

The Railway Siding Consultants and Contractors

THOS. W. WARD LTD

ALBION WORKS · SHEFFIELD

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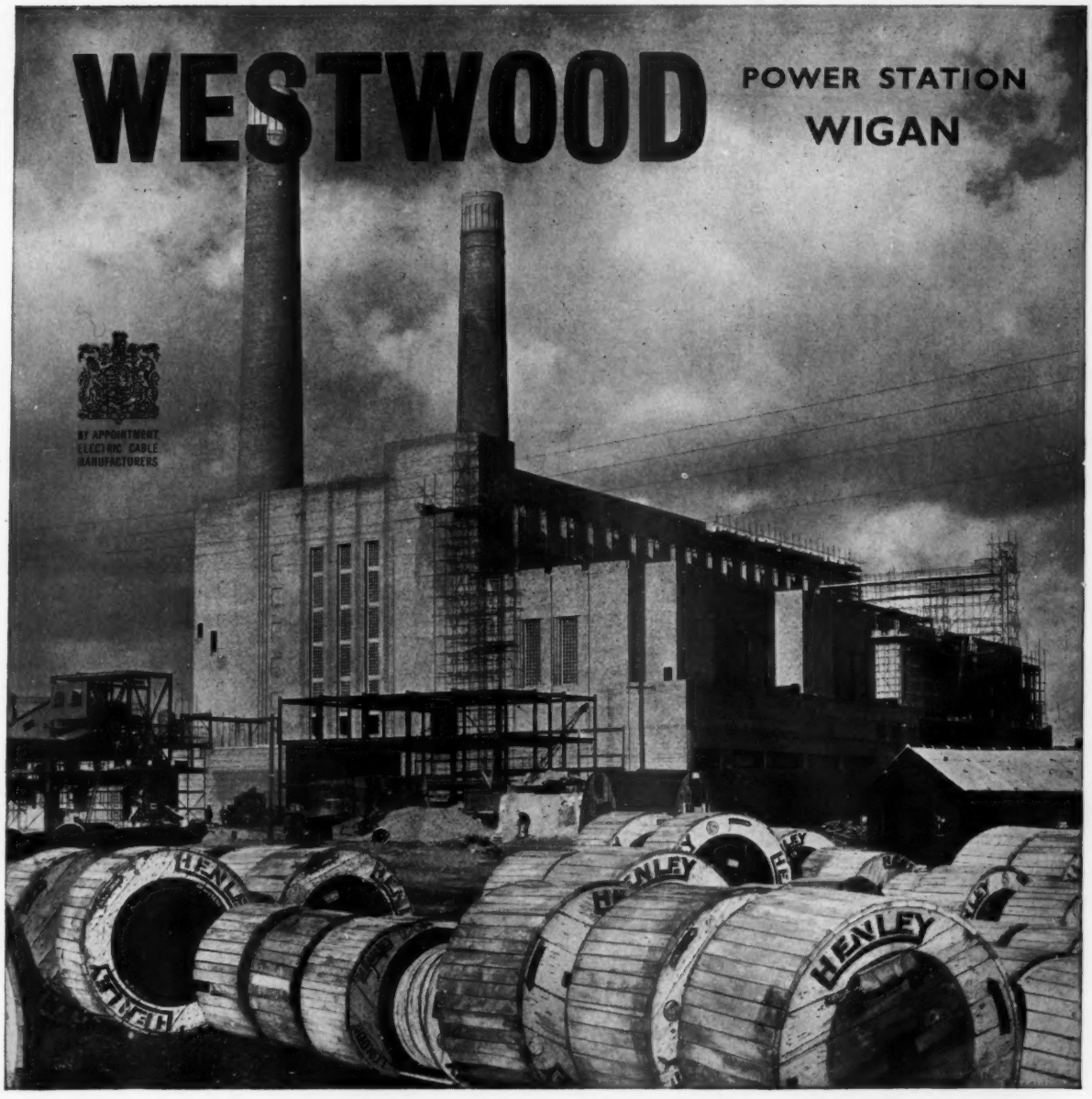


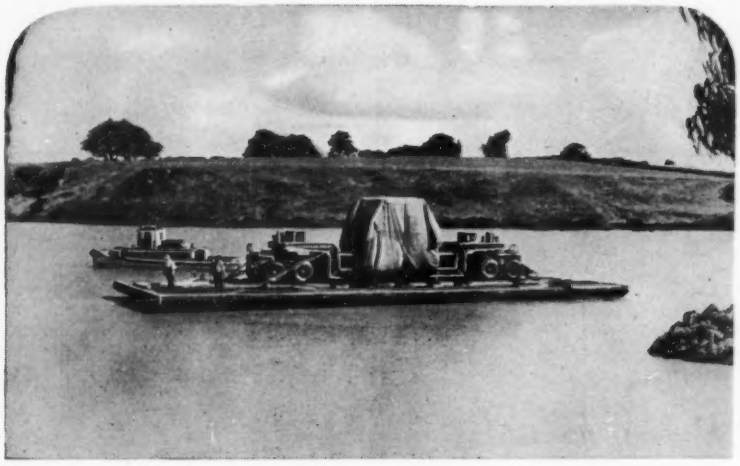
HENLEY'S were responsible for the entire cabling installation at Westwood Generating Station, Wigan.

HENLEY CABLES

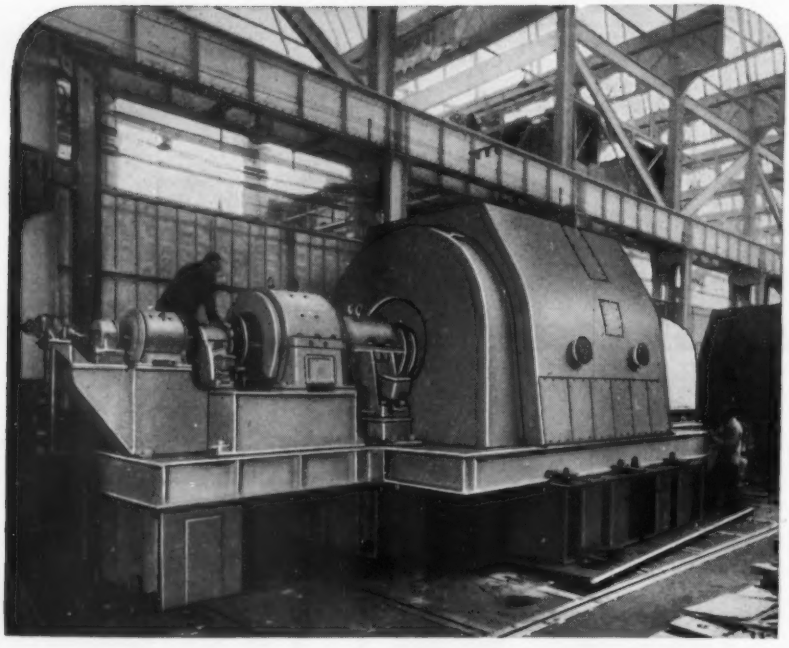
Consulting Engineers: Kennedy & Donkin

W. T. HENLEY'S TELEGRAPH WORKS CO. LTD., 51-53 HATTON GARDEN, LONDON, E.C.1

ELECTRIC EQUIPMENT *by* B T-H *for* **Hydro-electric Systems**



A natural source of perpetual power lies in the upland lakes and rivers of almost all countries. To harness it, BTH supply all plant required for hydro-electric power schemes.
The long experience of hydro-electric engineering possessed by BTH is one reason for the superiority of their equipment. Another is the exceptional capacity of the Rugby works, where plant on a very large scale, such as is required for many hydro-electric schemes, can be built and assembled without restriction.



One of the seven BTH 30,000-kVA., 750-r.p.m., 11,000-volt synchronous condensers supplied to, or in course of construction for, the State Hydro-electric Department, New Zealand. Above is shown a stator of one of the condensers during its journey in New Zealand from the docks to site.

For all plant required for Hydro-electric Power Schemes—**Consult BTH.**

Member of the AEI group of companies

THE
BRITISH THOMSON-HOUSTON
COMPANY LIMITED, RUGBY, ENGLAND

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Dominion Engineering

HYDRAULIC TURBINES

Water power has been a dominant factor in Canada's tremendous modern advance—and over half the water power developed in Canada has been harnessed by Dominion Engineering Hydraulic Turbines.

As its contribution to the world-wide development of hydro-electric power, in 1951 alone Dominion Engineering contracted to build, for Canada and abroad, Francis, Propeller and Impulse Type Turbines with a capacity of over 1,800,000 H.P.

The facilities and experience indicated by such a record are at your service anywhere in the world.

Write for General Bulletin No. 201 on Dominion Hydraulic Turbines.

Dominion Engineering Works at Montreal, Canada

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BRUCE PEEBLES

TRANSFORMERS

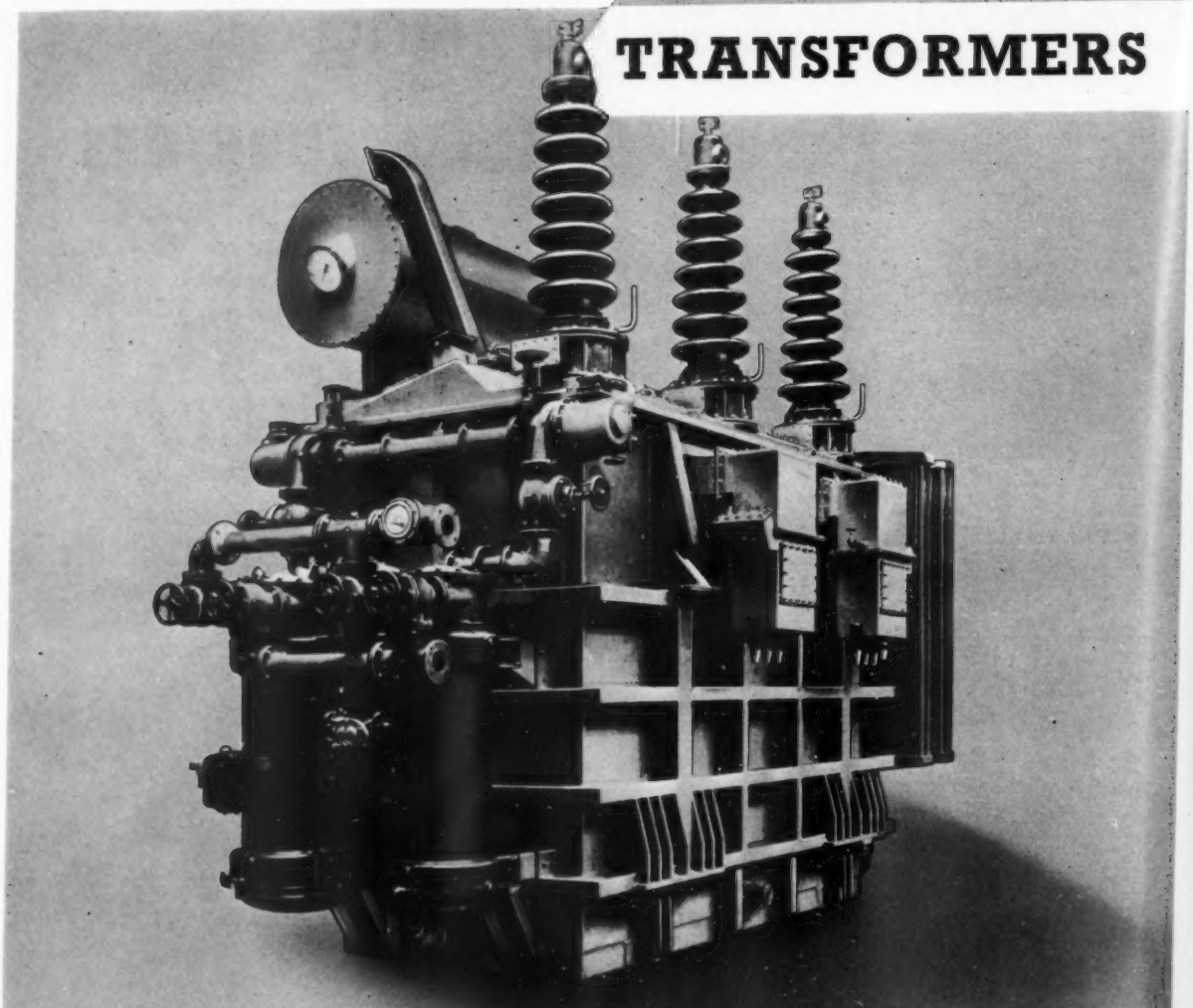
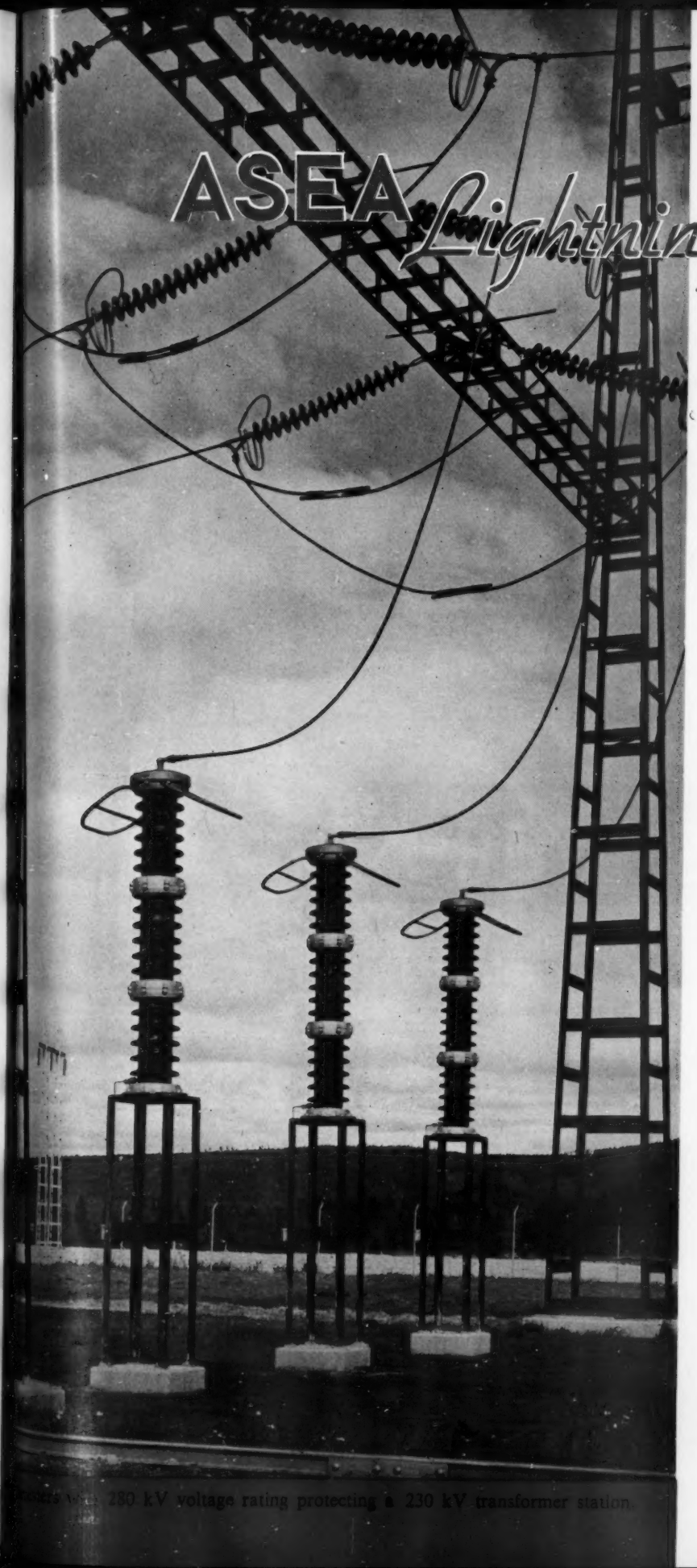


Illustration shows a 20,000 kVA, 132,000/11,000-volt water-cooled transformer typical of many supplied for Scottish hydro-electric schemes.

PEEBLES **TRANSFORMERS running into millions of kVA in units up to 75,000 kVA have been supplied for use all over the world, and larger equipments for the British Super-Grid are now on order.**

In practically every country you will find Bruce Peebles Transformers ranging from small pole mounting type to large power units.

BRUCE PEEBLES & CO. LTD., ENGINEERS, EDINBURGH



ers with 280 kV voltage rating protecting a 230 kV transformer station.

ASEA *Lightning Arresters*

—unrivalled for plant protection and service reliability

Outstanding features:

Low spark-over level at high impulse steepness

Low discharge voltage

Precision in manufacture: discharge voltage guaranteed to ± 5 per cent.

Perfect sealing

Built as a self-supporting column up to the highest ratings, with consequent low installation costs

★

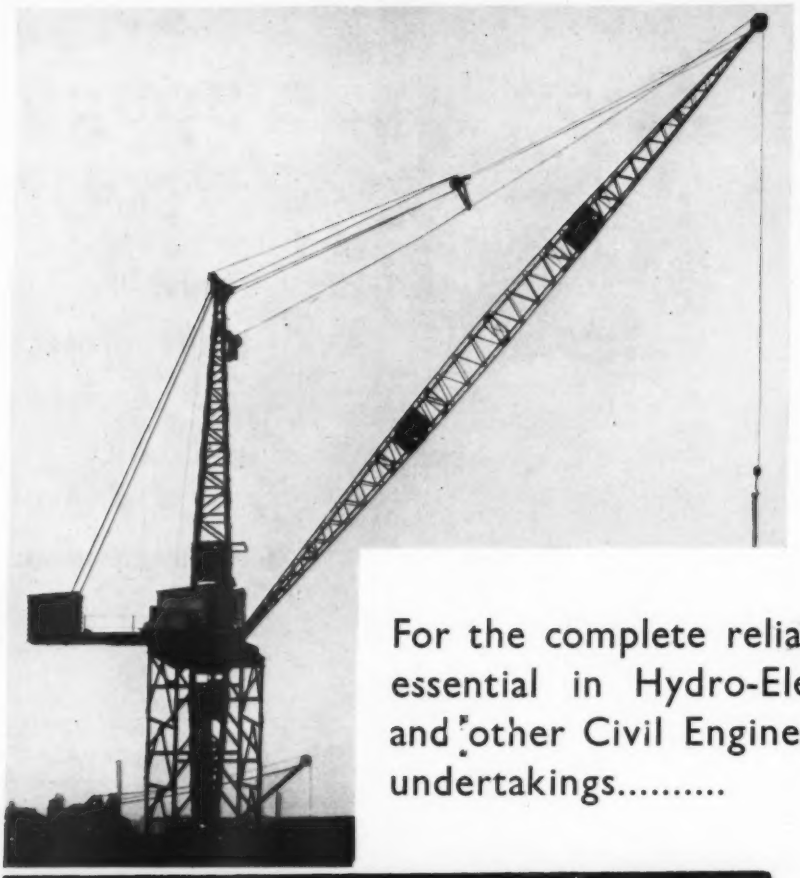
The arresters are manufactured in three different series according to their current rating: a heavy duty and a standard series tested according to the American Standards AIEE 28 A 1950 for Station Arresters (10 000 A) and a light series tested according to the same Standards for Line and Distribution Arresters (5000 A).

Standard Arresters for voltage ratings of 160 kV and below are held in stock. Short delivery time for larger arresters.

Write for pamphlet 7229 Ea.

ASEA

Västerås - Sweden



For the complete reliability essential in Hydro-Electric and other Civil Engineering undertakings.....

Butters Cranes

In over 80 years of specialised experience of crane building we have been privileged to supply cranes to many of the greatest hydro-electric and other civil engineering contracts ever undertaken, and have developed a considerable knowledge of operating conditions to be expected in most parts of the world. We are always happy to co-operate with engineers in deciding the most suitable types and sizes of cranes for any purpose and shall be pleased to submit designs and quotations on request.

The illustrations show a monotower (top) and a derrick crane, types which have had great success in Hydro-Electric developments and which we make in a variety of sizes and powers.

Butters Bros. & CO. LTD. ENGINEERS & CRANE BUILDERS

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GLASGOW, S.1, SCOTLAND

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Codes used: A.B.C. (5th Edition), A.1., LIEBERS and PRIVATE

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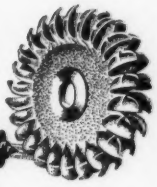
GILKES
for water power

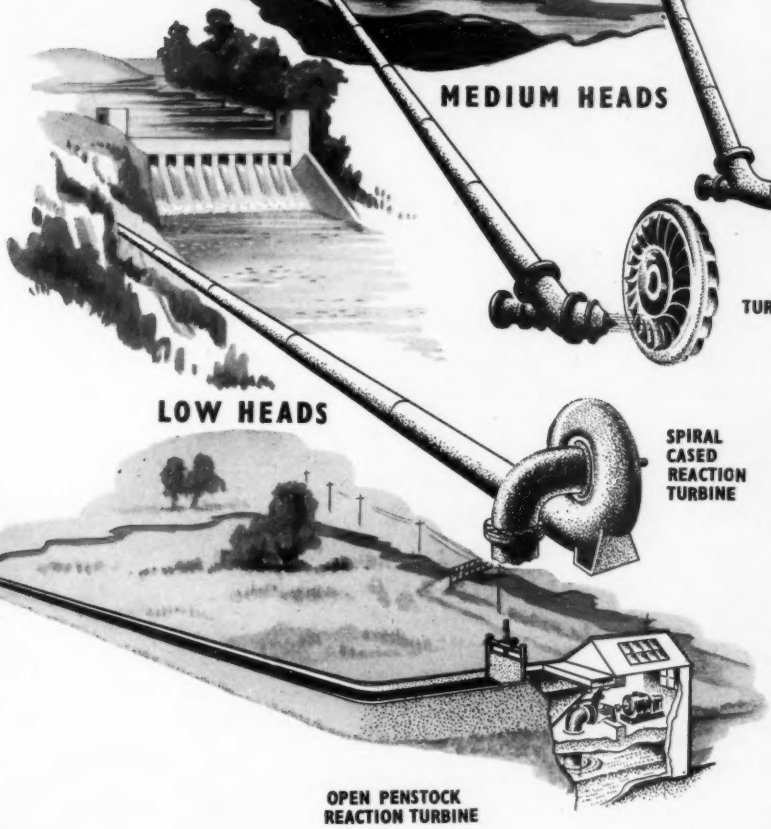
HIGH HEADS

MEDIUM HEADS



PELTON WHEEL

TURGO IMPULSE WHEEL



LOW HEADS

SPIRAL CASED REACTION TURBINE

OPEN PENSTOCK REACTION TURBINE

With the great and growing demand for electric power in most countries the question of developing this from water becomes increasingly important.

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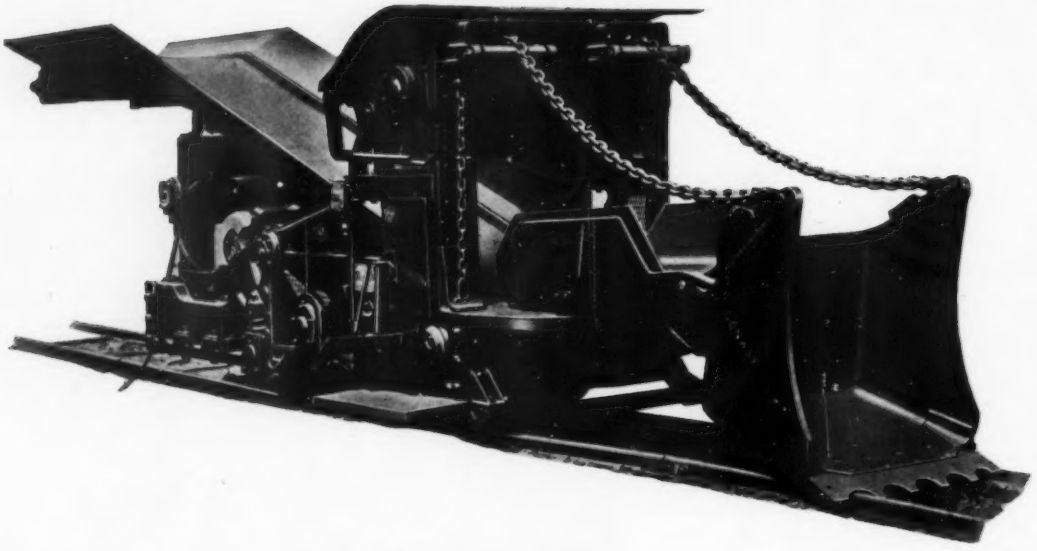

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Practical experience gained in the world's toughest tunnelling projects has inspired important improvements in the British Conway Loader. These exclusive modifications, detailed on the right, still further enhance Conway leadership.

Tunnelling with the Conway is now even more efficient, even more trouble free, even more economical.

The new Superlift Bucket with its manganese steel lip will load the hardest rock without risk of damage, and because provision has now been made for operating the Conway from either side, it is actually easier for the one man to operate the machine, easier for him to tram, root, swing or hoist.

Working with the Conway clutch operated endless belt conveyor, the loader will keep trucks or conveyors moving at the average rate of over 200 tons an hour. Let us give you a demonstration. ***Brochure free on request.***

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(Provisional patent No. 8304/52)

Embodying a simple, robust, radial-link attachment for the Hoisting Chains, whereby the force available for the initial heave of the bucket upward through the muck-pile is greatly increased.

2. SELF ALIGNING BEARINGS

Full "swivelling" type, carrying the Propellor Hoist and Conveyor driving shafts, raising transmission efficiency and reducing wear to a minimum.

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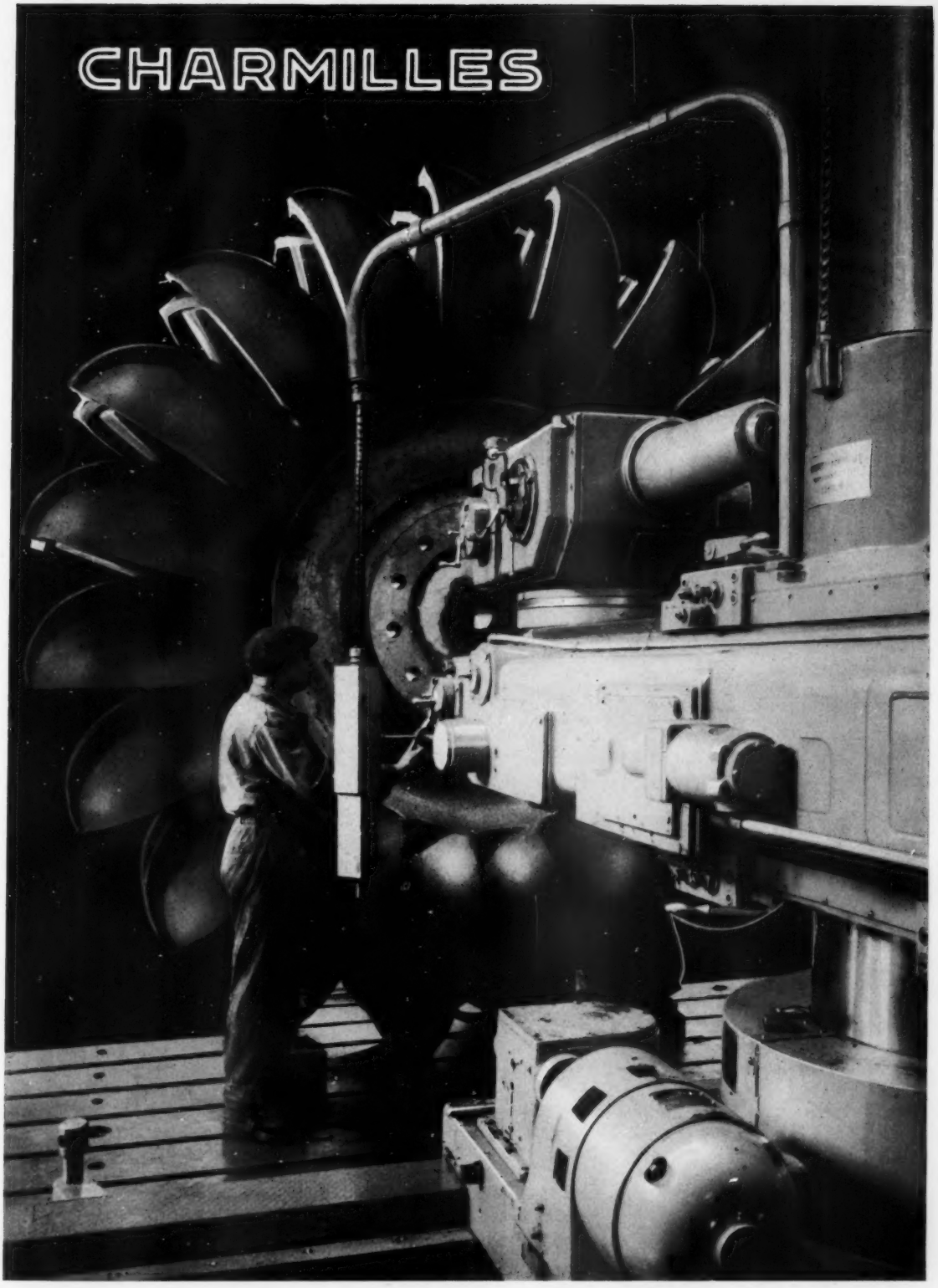

HYDRAULIC TURBINES

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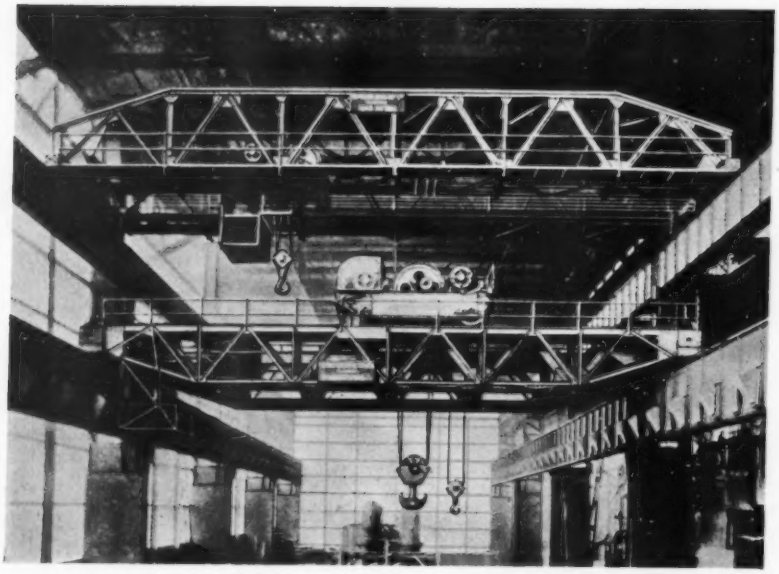
Arrol:

build many cranes. Their name-plate appears on the tallest tower cranes; the largest cranes (of 300 tons capacity) in any forge; the best designed steelworks cranes.

Cranes



Two Arrol Overhead Electric Travelling Cranes installed in a power station. Capacities are 175 tons and 30 tons, the former being provided with auxiliary hoisting also.

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Some power systems stick close to sea level . . . others are high in the mountains. No matter how rugged and exposed the terrain, however, the most efficient way to protect your electrical apparatus against lightning is to post Westinghouse Lightning Arresters on guard. When you specify Westinghouse Arresters you get all the protection you need against all kinds of line surges and overvoltages—at any altitude.

Case histories? Plenty of them. Take the difficult assignment recently completed for the Cerro de Pasco mining properties in the Peruvian Andes—tough country for any arresters. Teaming up with Ebasco Services, consulting engineers, Westinghouse supplied complete protection for valuable transformers at the new Paucartambo hydro project (altitude: 4,500 feet) and Cerro de Pasco's refining center at Oroya (altitude: 12,200 feet), which is served by Paucartambo.

Big reason for specifying Westinghouse Arresters at Cerro de Pasco, as well as for other tough jobs, is their unique unit design. Available in nine ratings from 3 kv to 37 kv, each unit is completely self-contained, consisting of an arrester element and a gap element. For high altitudes, extra electrodes are added to the gap without increasing its rating. Air-gap units are double sealed—once by their own cylinders and again by the arrester cylinders. Keep this exclusive Westinghouse unit design in mind when you're looking for lightning protection for any altitude . . . any voltage, from 3,000 up.

Write today for Bulletins DB 38-120 (large station-type arresters) . . . DB 38-130 (large distribution arresters for medium stations) . . . and DB 38-140 (distribution line-type arresters).

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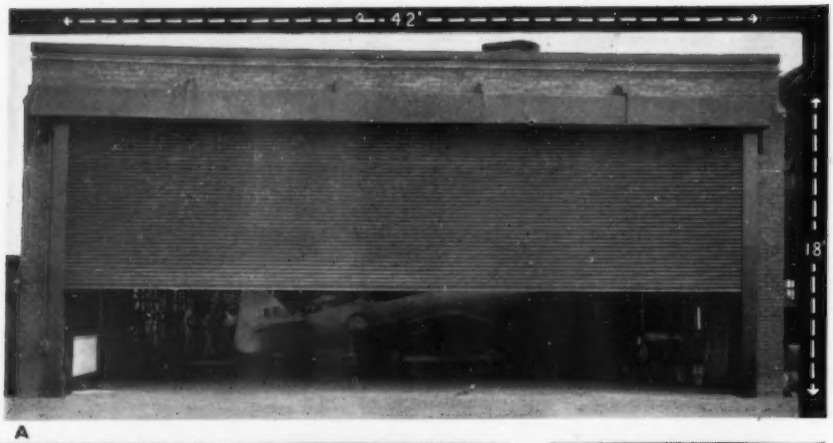
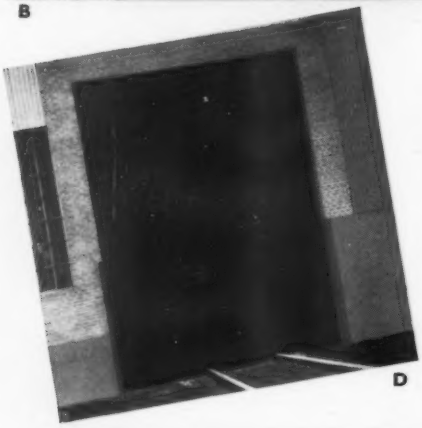


A

B

C



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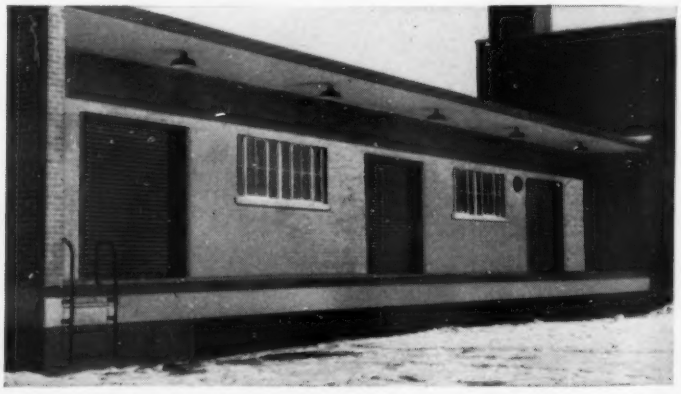

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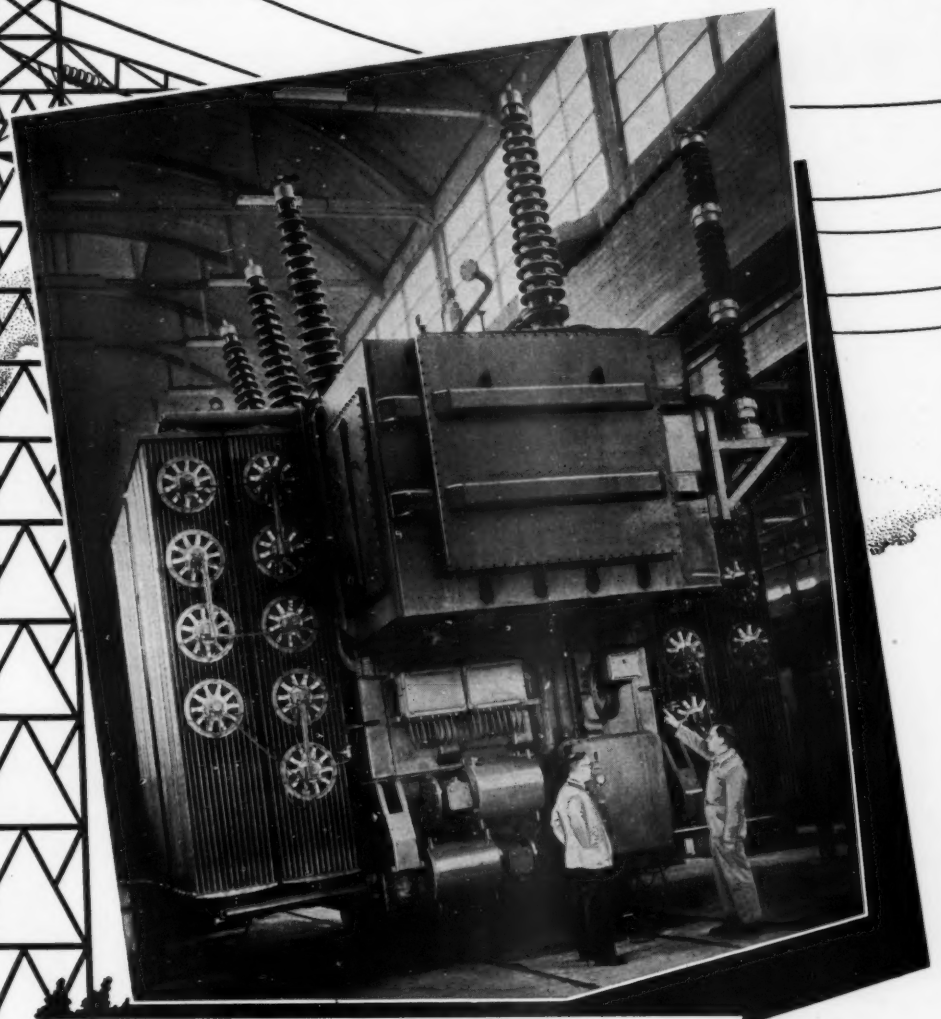

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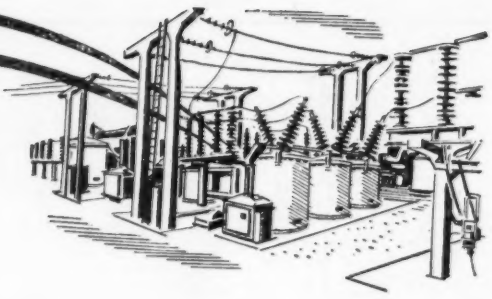

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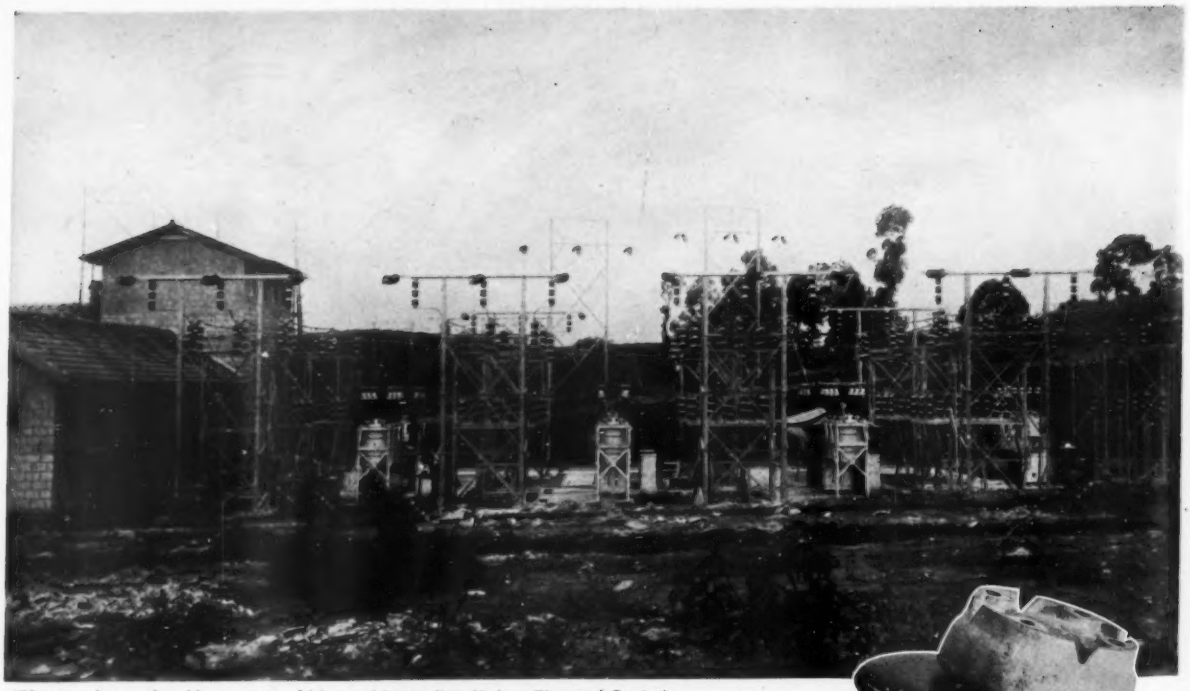

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The substation at Kothamangalam, Travancore, India, one of the 66kV substations on the Pallivasal project equipped with S.P.P. Post insulators type P.642.

S.P.P. POST INSULATORS were specified for all the 66kV outdoor switchgear on the Pallivasal Hydro Electric Scheme

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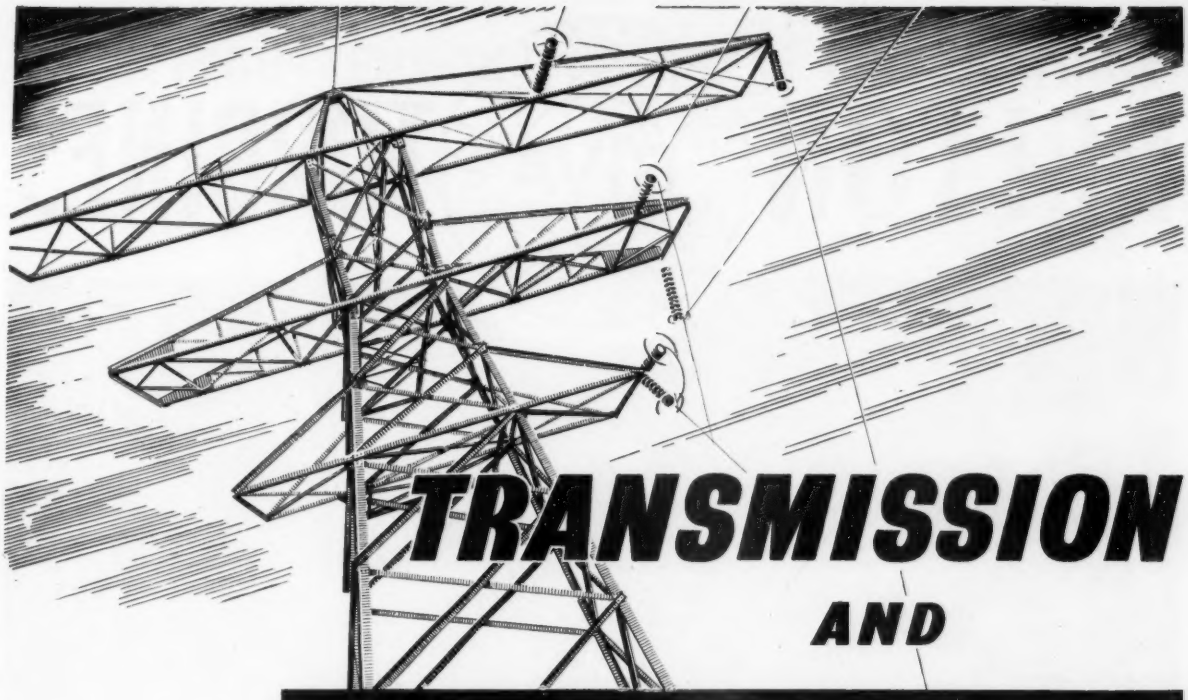

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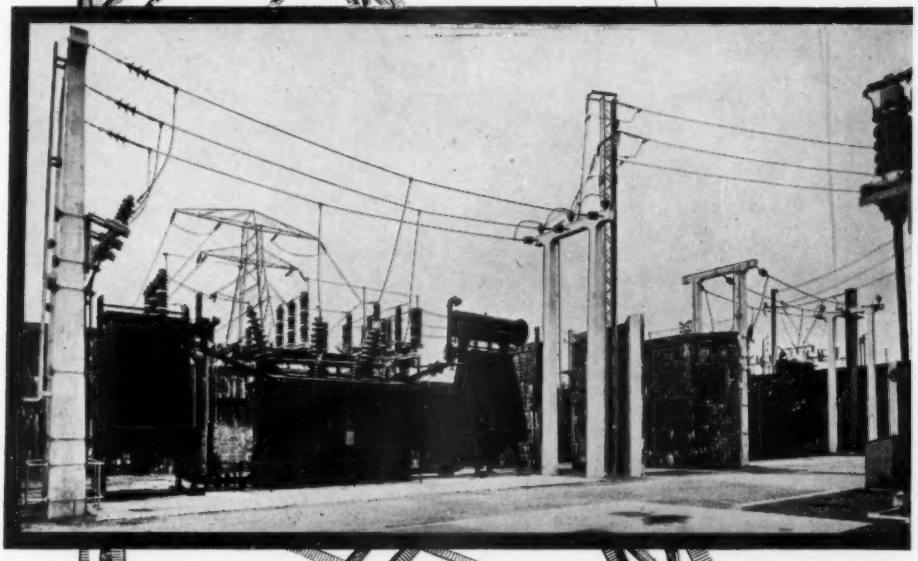

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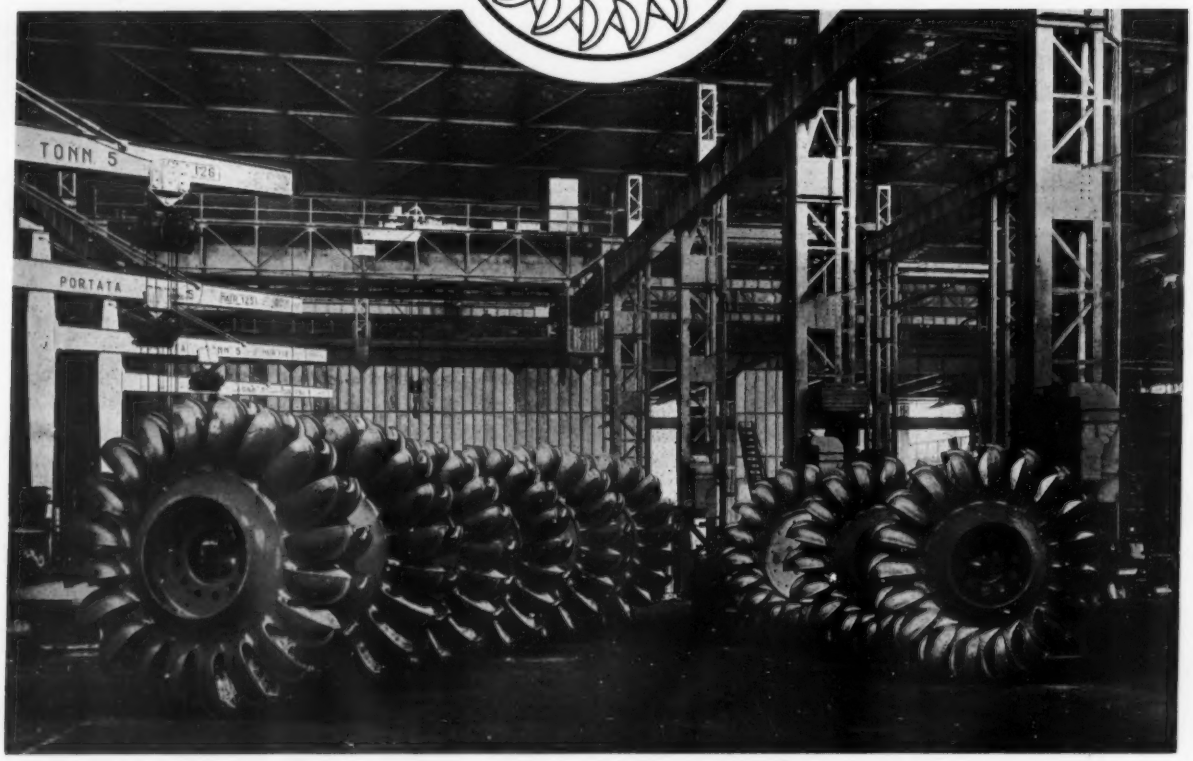

Cast Steel Runners for Riva Pelton Turbines of 80,000 H.P., 62,000 H.P. and 33,000 H.P.

Installations of special interest and importance include:

PELTON TURBINES. Impulse Units for heads up to 3,940 feet and outputs up to 110,000 H.P.

FRANCIS TURBINES. Two units each of 80,000 H.P. operating under a head of 930 feet and 3 Units each of 47,500 H.P.

KAPLAN TURBINES. Two Units of 33,000 H.P. each at 167 R.P.M. under a head of 91 feet

THE TOTAL OUTPUT OF PELTON, FRANCIS AND KAPLAN TURBINES DESIGNED AND BUILT BY RIVA EXCEEDS 8,000,000 H.P.

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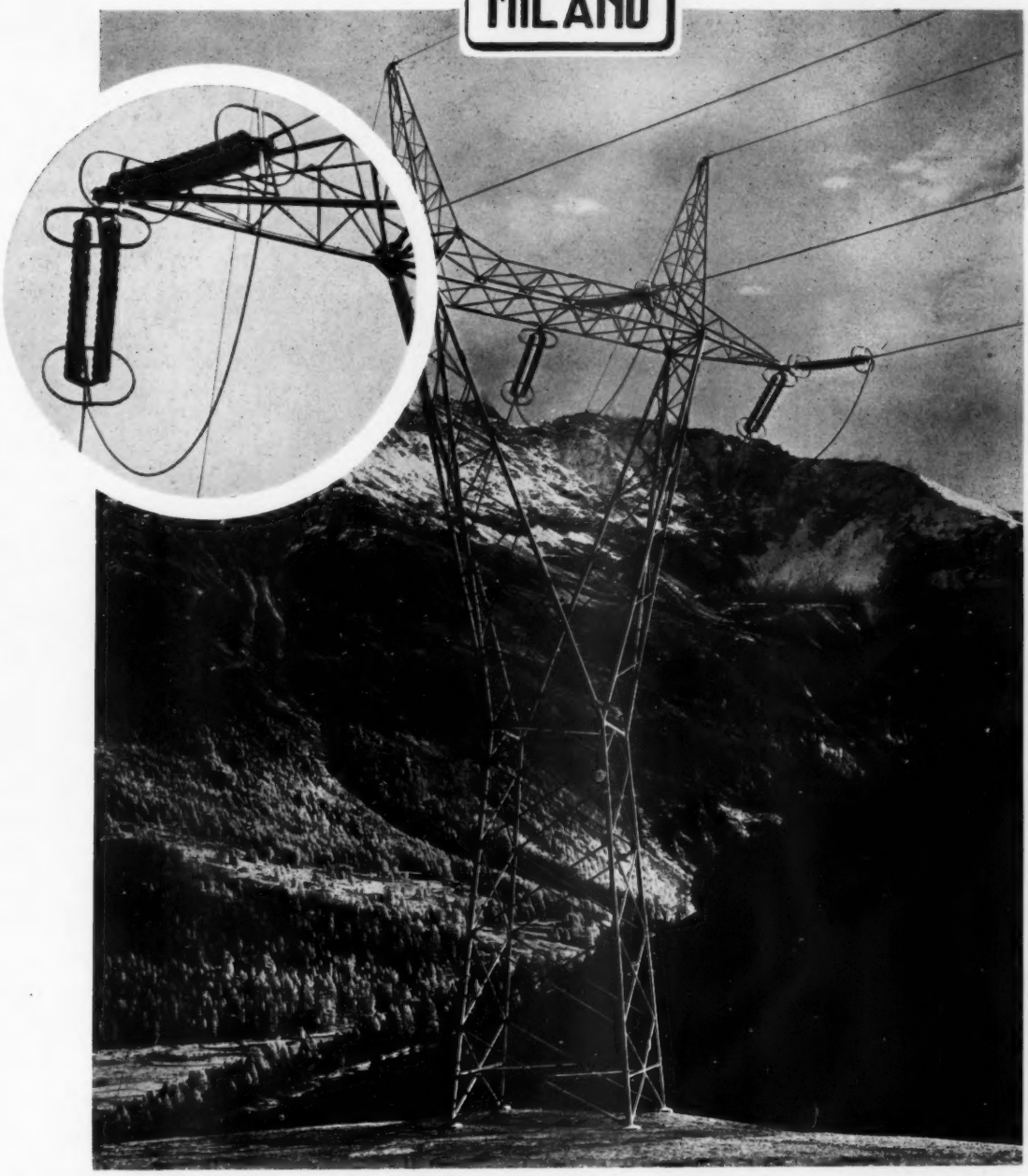

For 30 years Messrs. A. Salvi and Company, Milano, Italy, have specialised in the design and manufacture of complete equipment for Overhead Transmission Lines, including Compression Dead Ends, Assemblies and Joints. Suspension and Strain Clamps. Arcing Horns. Guard Rings. Shackles. Armour Rods. Galvanized Bolts and Nuts, etc.

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66 MW at 132 kV at FASNAKYLE

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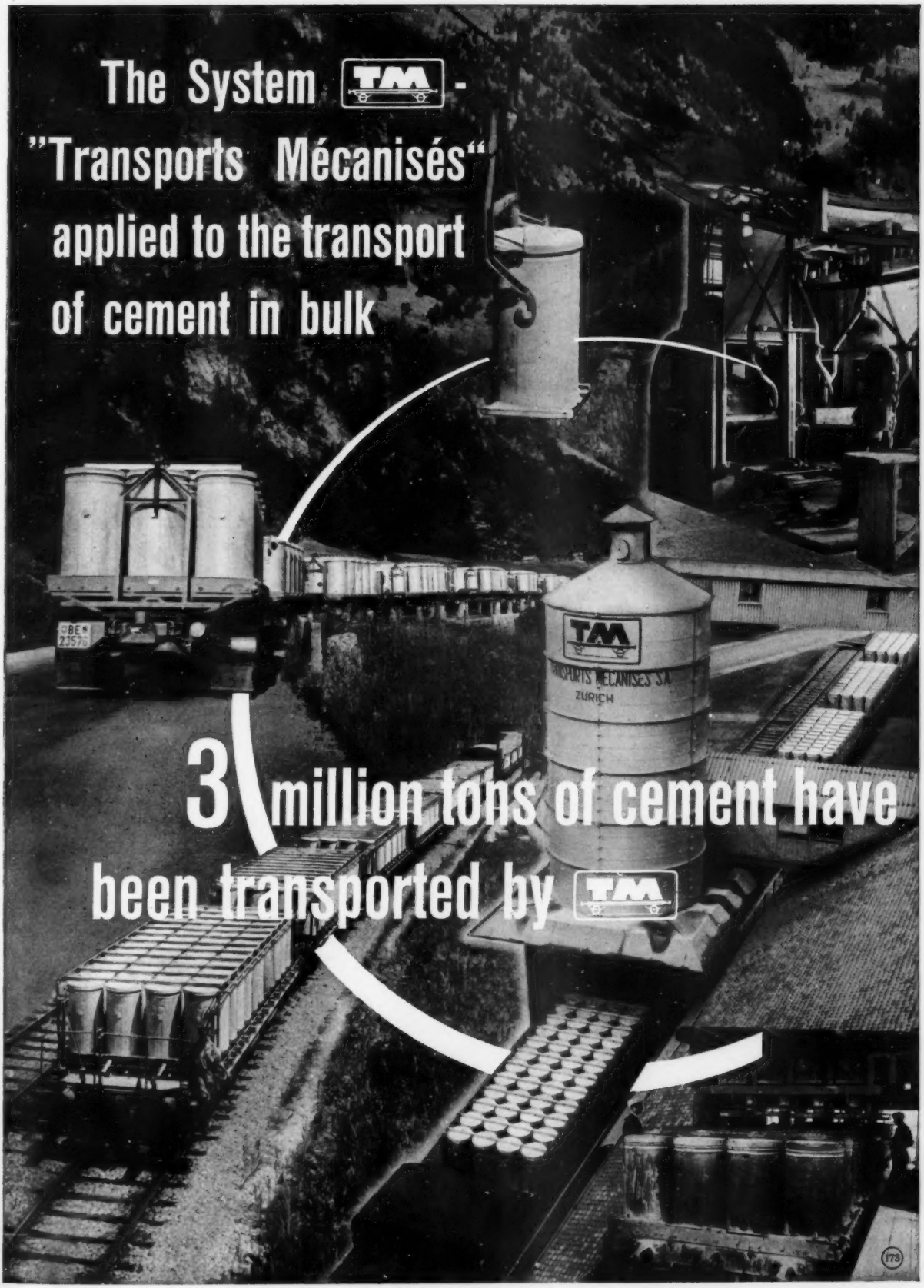
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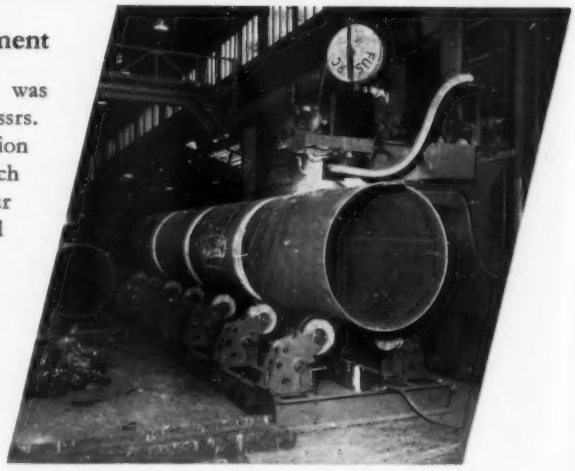
Another **FUSARC** achievement

This mechanical welding installation was designed by Fusarc in close co-operation with Messrs. Alexander Findlay who were responsible for the production of welded penstock pipes for the Gairloch project. Each finished length of pipe is 24′ long and made up in four sections each of 6 feet—diameters varied between 38″ and 48″. The Fusarc welding head is mounted on a cantilever overhanging the work so that it may be moved vertically to accommodate the varying pipe diameters and can traverse longitudinally (at controlled speeds) for welding the seams or for positioning over each circumferential seam. This installation is a typical example of how Fusarc-planned equipment gives greater welding productivity.



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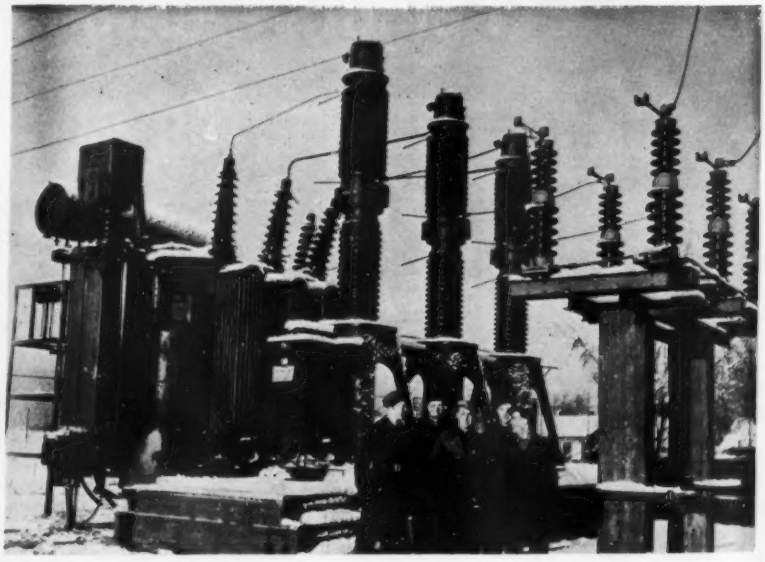
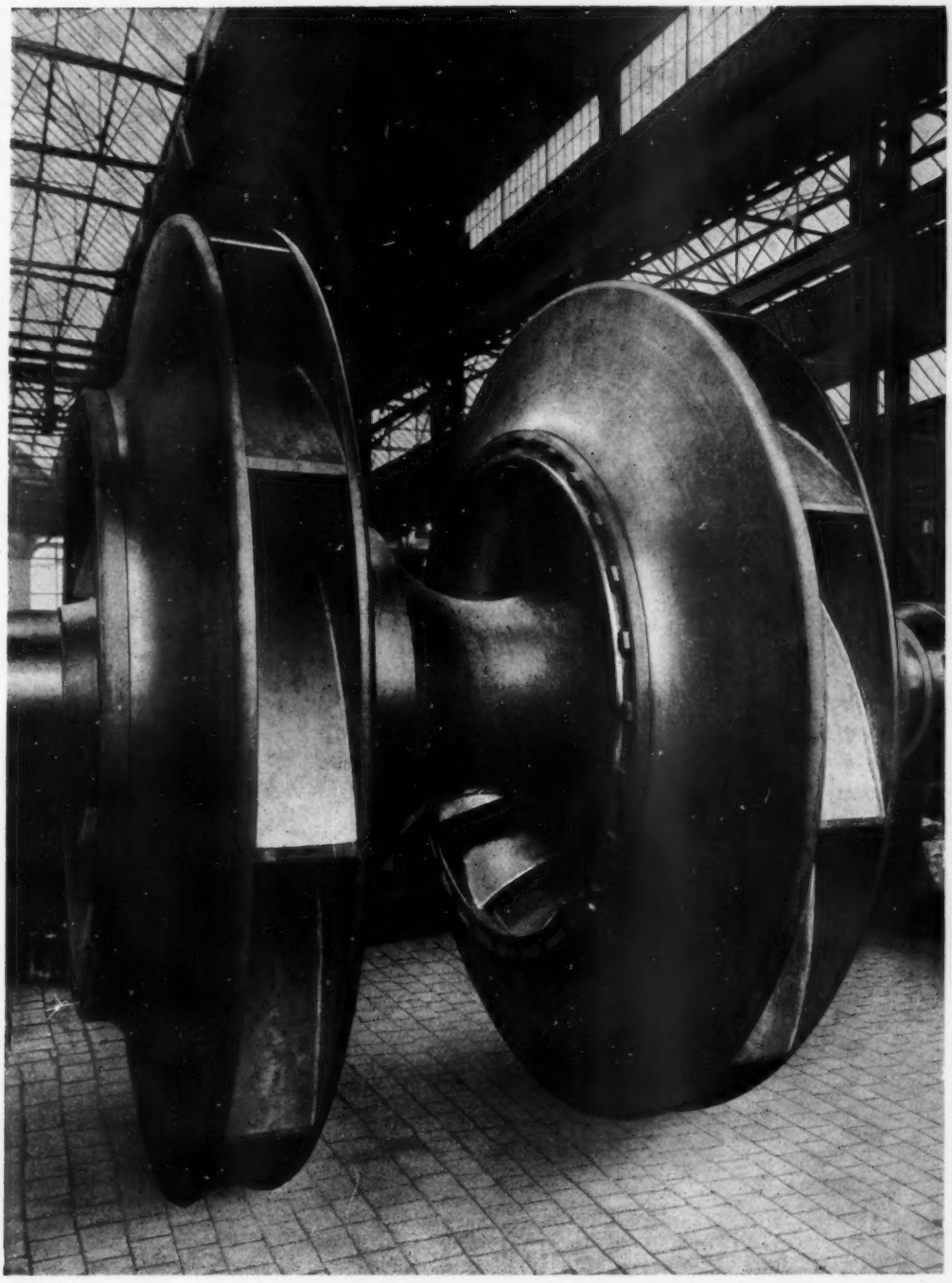


Low Oil Volume Circuit Breaker type PO/143, 140 kV. Supplied to Messrs. Rosenlaw & Co., Oy at Pori (Finland).



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Escher Wyss further specialize in Kaplan, Francis and Impulse turbines up to the largest outputs and heads, as also in other hydraulic equipment.

Our experience in manufacture and in installation work all over the world is at your disposal.

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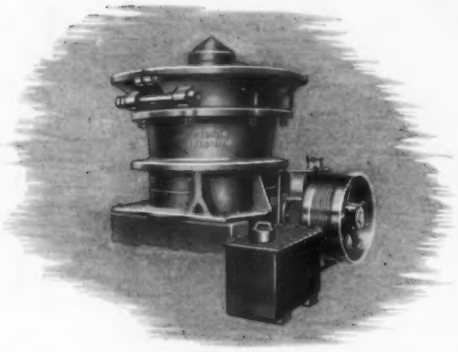

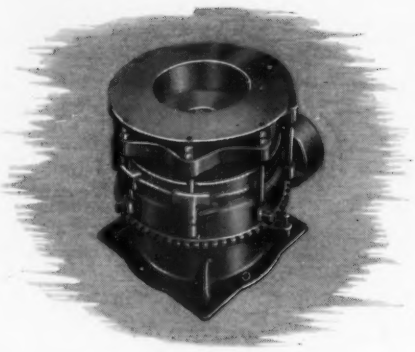

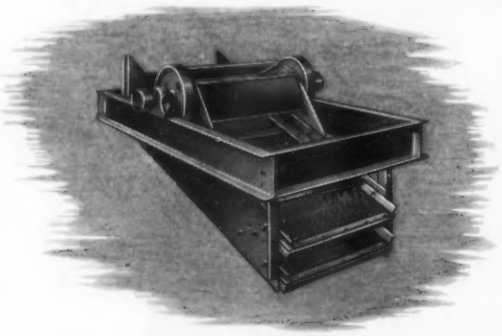

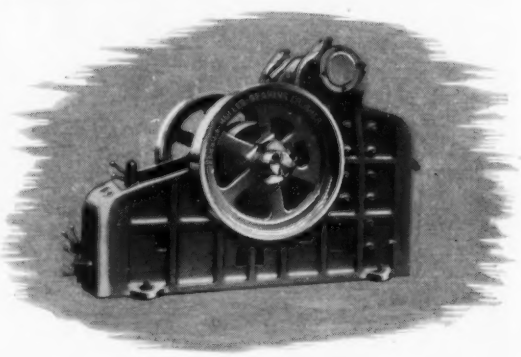

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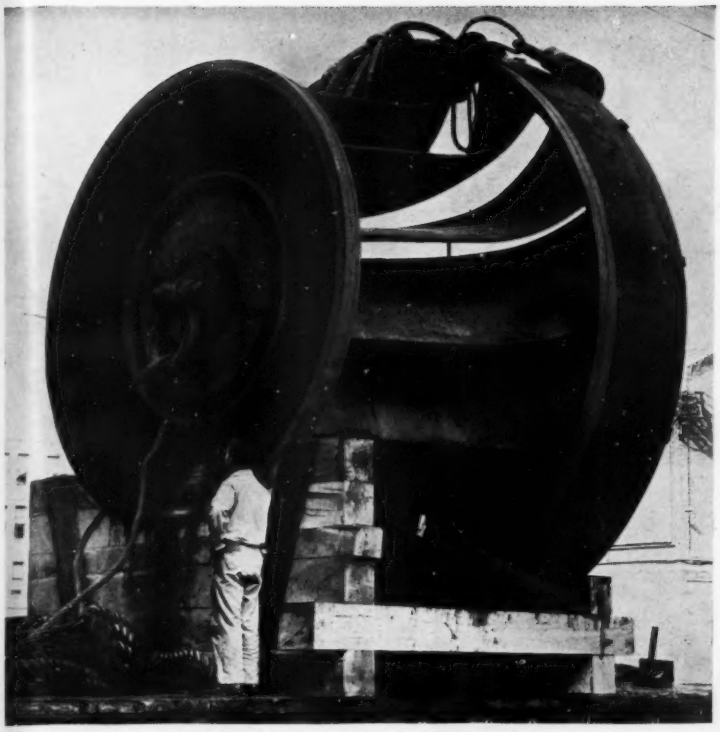

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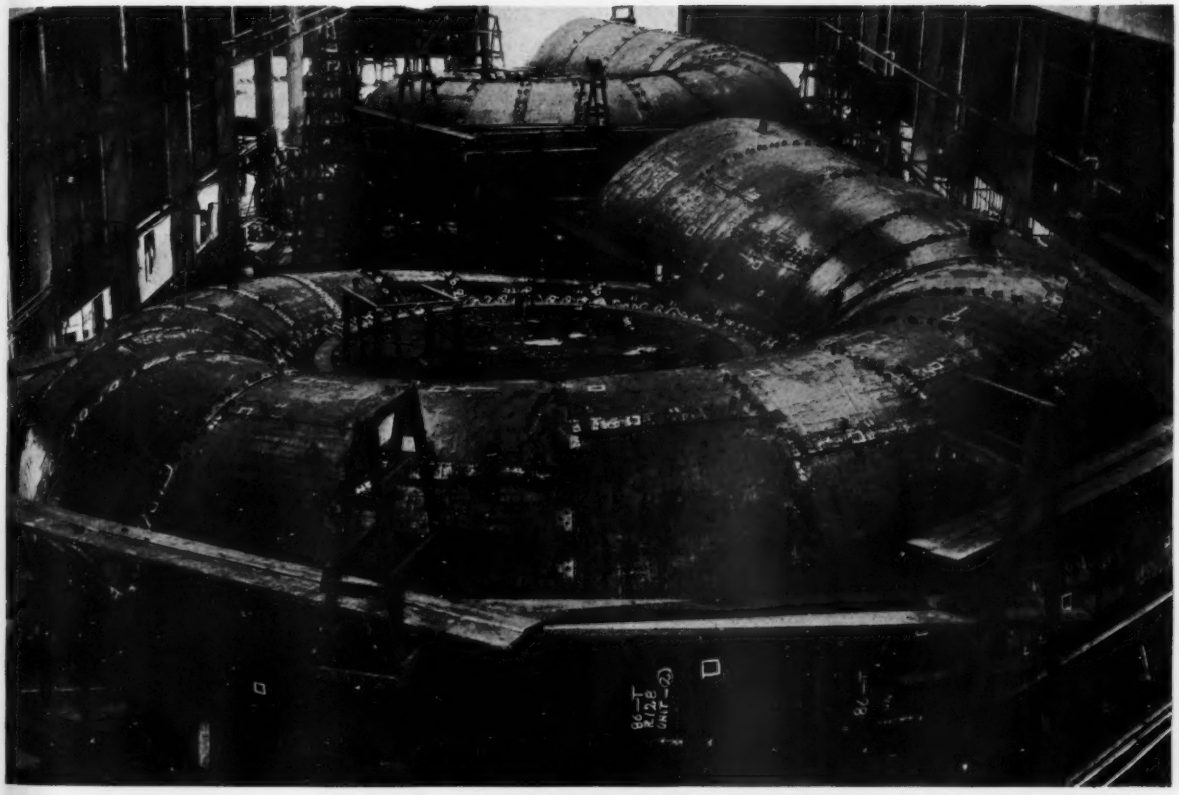

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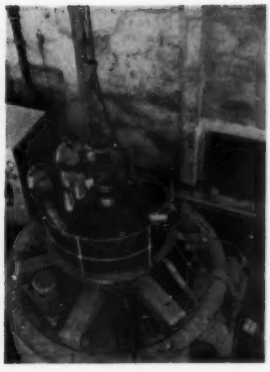

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VOLUME 4 NUMBER 11

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WATER POWER

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Tidal Power

THE United Nations Economic Commission for Europe has recently published a report on the "Prospects opened up by Technical Advances in Electric Power Production" in which some interesting particulars are given of the possibilities of developing tidal power. Much, of course, has been said about the Severn Barrage scheme, concerning which model investigations are now being actively undertaken, but other projects have almost escaped the public eye. The one for the Solway Firth, for instance, although it has never received much popular attention, has nearly double the potential of the Severn scheme, being based on an installed capacity of 1,005 MW and estimated to have an average output of 8,800 million kWh per annum. Other notable projects are those for Morecambe Bay with an installed capacity of 586 MW and a production of 5,100 million kWh per annum, and Carmarthen Bay, for which the equivalent figures are 370 MW and 3,000 million kWh respectively.

In France, also, besides Rance, Mont St. Michel Bay, and the Arguenon-Lancreux schemes which have received some attention, there are many other sites on the Brittany coast which have been subjected to preliminary investigation and it is now estimated that the total potentiality of the French tidal schemes may reach 20,000 million kWh. In addition, 41 sites have been selected as suitable for development along the Spanish coast, the Santona inlet of the River Asón, near Santander, on the northern coastline having been studied in detail.

It still remains to determine how far the majority of these schemes are practical on technical and financial grounds. Capital costs are naturally high and for the Rance and Mont St. Michel schemes the capital required would be in the neighbourhood of 70 per cent. more than for a run-of-stream hydro plant. On the other hand, the size of the unit involved favours cheap operating costs so that in all probability the cost of production would not amount to more than 55 per cent. above a normal hydro plant. On this point the Report cites the probable cost of production (on 1951 prices) at 0·16d. per kWh for the Severn Barrage scheme and 0·15d. for the Solway Firth project. The practicability of these schemes would thus appear to depend on the price of coal, which is still tending to rise. On this point the report reproduces figures which show very clearly how the increasing price of coal is tilting the economic balance in favour of the tidal schemes. In 1933, when the average price of coal was 15s. per ton, the Severn Barrage scheme could not have been economically justifiable with coal at less than 27s. per ton, so that the factor was 1·8 to unity in favour of thermal power. By 1949, however, when the prevailing price of coal was 58s. per ton, the factor in favour of thermal power had been reduced to 1·08 to unity. Since then, of course, the price of coal has risen considerably and although other costs have also increased, they have not increased in the same proportion and it is highly probable that the slight margin which existed in 1949 has now been wiped out.

It should not be forgotten that power production from an interconnected system of tidal plants would possess solid advantages. There would be no question of year-to-year fluctuations and the variation in total production between any two lunar months is sufficiently small to be almost negligible. On the other hand, of course, considerable day-to-day fluctuations have to be allowed for in any one plant, but with an interconnected system in which advantage could be taken of the diversity of tidal regimes at different points along a coast there is every prospect of obtaining large blocks of firm power at a cost commensurate with that of thermally generated electricity. Nor would the extreme daily fluctuations in production always be a bugbear as all the sites would not be of the single-cycle ebb-tide type. The scheme for the Chansey Islands in Mont St. Michel bay, for instance, envisages two-basin operation in which the fluctuations are largely reduced. In this system, it will be recalled, the two basins are operated on a single cycle with one

basin generating energy during filling and the other during emptying. But if circumstances permit, a second variation is possible in which the power station is placed between the two basins, the sluices allowing the water to enter one basin from the sea and leave the other during part of the time when water is also passing through the turbines between the two basins. A further variant lies in having three basins, with the object of achieving maximum production by maintaining the greatest possible mean difference in water level. Where the topography of the surrounding terrain favours the installation of a pump-storage system an enormous advantage would accrue, as this would enable peak-load current to be produced and all dependence on daily fluctuations to be severed.

Based on double-basin schemes, it has been estimated by G. S. Collyns* that 35,000 million kWh could be generated per annum from plants situated along the west coast of Great Britain. Of the schemes which he considered practicable and which would not interfere with shipping, he cites the Solway, Morecambe Bay, Carmarthen Bay and the Severn Barrage No. 2 schemes, all of which he estimates as being capable of generating current at a cost not exceeding 0·3d. per kWh at 1951 prices. As the recently published B.E.A. report (1950-1951) gives a generating cost of slightly over 1d. per kWh, it would seem that a clear case exists for paying every attention to the potentialities of tidal power schemes.

Progress in Portugal

IN a paragraph headed "Difficulties in Portugal," published on page 363 of our October issue, in which it was stated that the Vila Nova programme had fallen behind schedule because of the difficult financial situation, we are now assured that we have been misinformed on this point. The facts of the case are that while the first of the Vila Nova Pelton-generator sets was put into service in June 1951, as was stated, there was no question of the other three sets being held up: actually the second of the sets was put to work with one wheel in September 1951, the second wheel being added in March 1952. The third set was put into commission shortly afterwards, *i.e.* in June 1952. In consequence the first stage of the scheme, which comprises the harnessing of rivers Cávado and Rabagão by three Pelton-driven generator sets, is now fully completed and in operation.

Nor will there be any delay in completing the second stage of the scheme—the Salamonde stage—consisting of two Francis turbine sets of 29,600 h.p., which will come into operation next year. Furthermore, the Caniçada stage has already been begun and is scheduled for completion in 1954; here the two turbine sets will also be of the Francis type but will be of 42,600 h.p.

The Vila Nova station will eventually be provided with a further Pelton set of 39,000 h.p. to deal with the water of the Paradela; this will complete the fourth and final stage, details of which are now being worked out by the engineering department of Hidro Eléctric do Cávado.

We are also informed that the Portuguese Government, to which belongs the credit for initiating these and other important works, is submitting to the National Assembly a further programme of development, covering the next six years, in which the exploitation of the Douro basin will occupy a prominent place.

* "The Production of Tidal Power by the Two-Basin System." *Engineering*. Vol. 171, 1951.

Winnipeg Projects

THE annual report for 1951 of the City of Winnipeg Hydro-Electric System states that the flow of the Winnipeg river past the Pointe du Bois and Slave Falls plants continued to be well in excess of the firm load requirements of the City Hydro System. All load demands were met by the hydraulic plants, which produced about 865 million kWh per annum. Of this amount about 355 million kWh were supplied as off-peak energy to electric boilers. The installation of the new 15,000 kW steam turbine generator, No. 3 of the main unit in the Amy Street plant, was not completed to schedule because of delay in deliveries. Progress reports on the supply of the 25,000 kW steam turbine generator, the fourth and final unit in the plant, indicated that it would be completed to schedule in 1953 unless prevented by scarcity of materials such as steel and copper.

Catalagazi

THE new hydro-electric station at Catalagazi, in north-west Turkey, which is to serve the whole of Istanbul area, as well as the important industrial belt of Eregli, and the naval base of Golcuk, was tested out in August and has now gone into regular operation. The 60,000 kW generated at Catalagazi is being distributed by way of three transformer stations, one at Eregli, for 3 × 12,500 kVA, one at Izmit with 2 × 7,500 kVA and the third at Istanbul with 3 × 12,000 kVA.

Japanese Development

A BILL for the development of the country's power resources has been passed by the Japanese Upper House, the House of Councillors, but not without controversy. The Bill, with amendments, will still have to be referred to the Lower House. Criticism has been centred on the Government's proposals and no compromise has yet been reached between the promoters and their opponents. In the Bill exploitation of such rivers as the Tadami, Kitakami, Kuma, etc., are proposed, but the Government is understood to be aiming also at the exploitation of rivers like the Tenryu, Kumano, and Yoshino, where existing companies are proposing to put up their own generating plants. The Bill calls for establishment of a corporation to carry out these projects but it is not clear whether the corporation is to engage in the selling of the generated power. When the Bill was first brought before the Diet it was generally understood that the corporation would devote itself to the development of power resources and that selling would be undertaken when it did not conflict with the primary objective. Opponents of the Bill have pressed for the establishment of regional power development companies as private interests.

Swiss Consumption

AS a result of the favourable economic situation, Switzerland's consumption of electric power during the year ended September 30, 1951, showed an unprecedented increase, according to the Bulletin of the Swiss Bank Corporation. Compared with 10,318 million kWh generated in 1949-50, the 1950-51 figure of 12,191 million kWh represented an increase of 1,873 million kWh or 18·2 per cent. In the main the increase was made possible by the larger volume of water carried by the rivers and only a small fraction (308 million kWh) represented production from new power stations. Thermal generators, under 56 million kWh (161 million kWh in 1949-50) made only a small contribution.

Normal consumption, i.e. not including boilers and pumps, increased from 8,973 million kWh in 1949-50 to 10,429 million kWh in 1950-51, an increase of 1,456 million kWh, and total consumption rose from 9,885 million kWh to 11,554 million kWh.

The Sariyar Dam, Turkey

PREPARATIONS for the main construction work on this scheme are now complete, and power production is scheduled to commence in April 1955. The annual output is expected to be 350 million kWh, of which Istanbul will absorb 200 million kWh, Ankara 100 million kWh, and Eskisehir and Basra the balance. The dam will be 27 m. high from the river bed, 70 m. wide, and the pondage will be 1,600 million cu. m., most of which will be derived from the Sakarya river.

Sarobi Handicaps

GERMAN technologists and engineers are busy in Sarobi, with thousands of Afghans, constructing one of the three largest hydro-electric stations in Afghanistan. The work was started about a year ago and when completed the station will be able to meet an average maximum winter load of 16,000 kW. At present about 12,000 kW are being generated in Afghanistan in some half-a-dozen plants. This power is now being mainly absorbed by the lighting load and by a textile mill. The Arghander and Kajakai schemes, which are being engineered by Americans, will eventually have a capacity of 85,000 kW and 120,000 kW respectively. Progress on the Sarobi station is being hampered by the difficulty of transporting machinery from Karachi and the station is not expected to be complete for another three years.

Mysore Project

M. HAYATH, an expert engaged by the Economic Commission for Asia and the Far East, has at the invitation of the Government of India worked out a preliminary plan for the further development of hydro-electric power in Mysore. The project provides for the building of a storage dam in the Sharavatti valley and according to Mr. Hayath's recommendation, the scheme (so named from the village where the reservoir is to be situated) should be put into effect in two stages of 170,000 kW capacity each.

This scheme is essentially a sister project in the same river valley as the Mahatma Gandhi hydro-electric works, at which the installed capacity of 120,000 kW will eventually be trebled, making a total of 460,000 kW. It is hoped that financial approval for the new scheme will be forthcoming in the near future and that work on the dam will begin some time next year.

The first stage of the work should be completed in about nine years, and is estimated to cost Rs. 226 million.

Record Output at Grand Coulee

AMERICA is traditionally the land of records; and we have heard on more than one occasion of the immense figures of output reached at the Grand Coulee plant in the Columbia River valley. With its eighteen 108,000 kW units — the largest individual hydro-electric generating sets in the world—it is only to be expected that record production figures can be achieved. A new world record power production from a single-hydro-electric plant was claimed in July this year, when the station's output reached 2,252,000 kWh in one hour.

The station is remarkable not only for the very great size of the dam and the very high figure of 1,974,000 kW installed, but also for the fact that it contains the world's largest pumping installation in addition, with pumps absorbing 65,000 h.p. each.

Progress in Sierra Leone

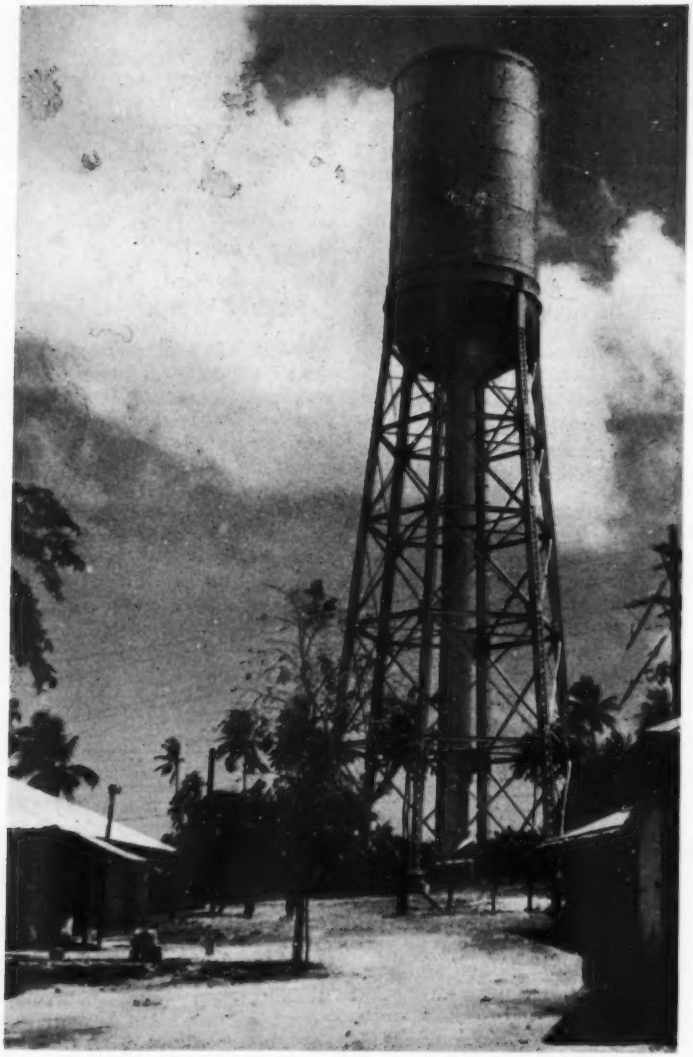
WE understand that the Sierra Leone Legislative Council has adopted a motion approving the Guma Valley hydro-electric and water supply scheme, and that British Government grants are being made available.

The Guma Valley project will bring water supplies and hydro-electric power, all the year round, to the districts of Hastings and Waterloo, and will augment the electricity supply to Freetown, the capital of this West African territory. An estimated figure for the cost of the project is of the order of £2½ million and it is thought that the work will take about four and a half years to complete.

The World Power Conference

A RECENT note in these columns mentioned the provisional arrangements for the Sectional Meeting of the World Power Conference to be held in Rio de Janeiro from July 25 to August 8, 1954. It is now learned that the French National Committee are likely next year to issue a formal invitation to the Conference to hold the Fifth Plenary World Power Conference in Paris in 1956. It is also understood that the Canadian National Committee will invite the Conference to hold a Sectional Meeting in Canada in 1958.

The Allied Congress on Large Dams is to hold its fifth Meeting in Paris in 1955, and Mr. Gail A. Hathaway, of the U.S.A., has replaced M. Coyne as Chairman of the W.P.C. International Commission on Large Dams. This was announced at the Executive Meeting held in Chicago on September 5.



Surge tower with woodstave pipeline joining steel pipe at base

The Lower White River Scheme—I

H. D. Morgan, M.Sc., M.I.C.E., and N. J. Cochrane, B.Sc., A.M.I.C.E. (both of Sir William Halcrow and Partners, MM.I.C.E.), describe some of the civil-engineering problems that had to be solved in the construction of this important Jamaican scheme. A further article on the mechanical and electrical aspects of the scheme will appear in our next issue.

THE Lower White River hydro-electric scheme is the latest of a series of power developments carried out in Jamaica by the Jamaica Public Service Company. This company, which holds a long-standing concession for the supply and distribution of electrical power in the island, is a good example of the many public utilities companies which have done so much to advance the economy of some of our Colonial and Commonwealth territories. Its history reflects very fairly the change in the economic and

social life of Jamaica from a long-established and predominantly agricultural society to one with a substantial proportion of industrial activities, and indeed some heavy industries as, for example, the production of cement and the mining and export of bauxite and even its conversion to alumina. For such a change to take place, the supply of power at economic cost is an essential. The effect is cumulative and the results in the early years may not be striking. It is only within the past twenty years or so that the progression of events in Jamaica has been rapid. Against this may be set the fact that the Service Company has in operation at Bog Walk one of the earliest hydro-electric plants built for public supply some 55 years ago. This plant was remodelled about ten years ago.

Apart from this old station, one oil-fired steam generating station and some smaller diesel stations, the company has completed in recent years three modern hydro-electric developments in the north of the island, at Roaring River and at Upper and Lower White River. This article is concerned with the civil-engineering aspects of the last of these, which came into service during the early part of 1952.

Topographical and Geological

The island has a varied topography which is everywhere interesting and in places spectacular. Its centre is taken up by a spine of fairly high mountains with numerous foothills running down to the sea. There are a few flat coastal areas but the country in general is deeply eroded and rugged though scarcely ever barren.

The greater proportion of the geological structure consists of limestones, marls and similar sediments. Local interchanges in the type of rock are frequent and the dominant limestones are usually fissured and pervious.

The winning of hard sands and stone for the making of concrete or for road metal is both tedious and discouraging. The limestones in themselves are not often hard enough to be used for such purposes but they contain harder concretions which are weathered out on the hillsides and then collected and broken down by hand into aggregate. Rather chalky sands may be found in the rivers or at their mouths.

Meteorological and Hydrological

Jamaica has a normal tropical climate. Temperature and humidity remain high for the whole of the year, the shade and night temperature rarely falling below 75°F. or rising above 95°. Rainfall is of tropical intensity but the total is not more than about 80 inches per year falling in two very approximate wet seasons.

Fig. 2. Canal between Upper White River station and headpond

As a general rule there is hardly ever a simple relationship between rainfall and river flow except for rivers in temperate climates where the evaporation and transpiration are a small proportion of the rainfall and where the underlying rock is relatively impervious. In the more mountainous parts of Great Britain the total run-off is of the order of 90 per cent. of the rainfall, but this value reduces to about 50 per cent. for mountain rivers in say Portugal and may have fallen to between 5 and 10 per cent. for many tropical and equatorial rivers. In some cases it may be as low as 1 or 2 per cent. because of enormous evaporation. Attempts to forecast the behaviour of even perennial tropical and equatorial rivers from the rainfall on their catchments, therefore, are highly speculative unless there are a reasonable number of actual river-flow measurements. For example, when a river is said to have a run-off of say 5 per cent. of the rainfall, it would be more apt to state that the losses due to evaporation, transpiration, and other natural causes are not less than 95 per cent. of the rainfall. A very small change of say one-twentieth in these heavy losses might be caused by a small change in general meteorological conditions and the actual flow in the river might be doubled or it might dry up completely. This particular aspect of river flow is not always appreciated, or if it is appreciated it is seldom emphasised.

In Jamaica the problem is even more complicated since much of the area consists of marls and permeable limestones, generally fissured and often distinctly coralline. In such conditions direct run-off is very limited and a great proportion of the rain disappears into the ground. Some of this reappears in the form of springs, of which several are large and form the sources of rivers.

The White River in the north of the island is one of these, and the greater part of its flow comes from a large spring rising in the vicinity of Mount Plenty about half-way along its topographical river valley. The total amount of water running directly from the upper half of the river is relatively small and generally in the form of spates after heavy rainstorms. Roughly in the centre of the island is a large upland basin known as the Moneague, and it has been suggested that a great part of the flow of the White and other rivers derives from the rainfall on this basin.

A great underground storage phenomenon is undoubtedly active in the centre of the island, and this

Fig. 3. Canal under construction, with temporary diversion to river bed
Fig. 4 (below). General map of Lower White River scheme

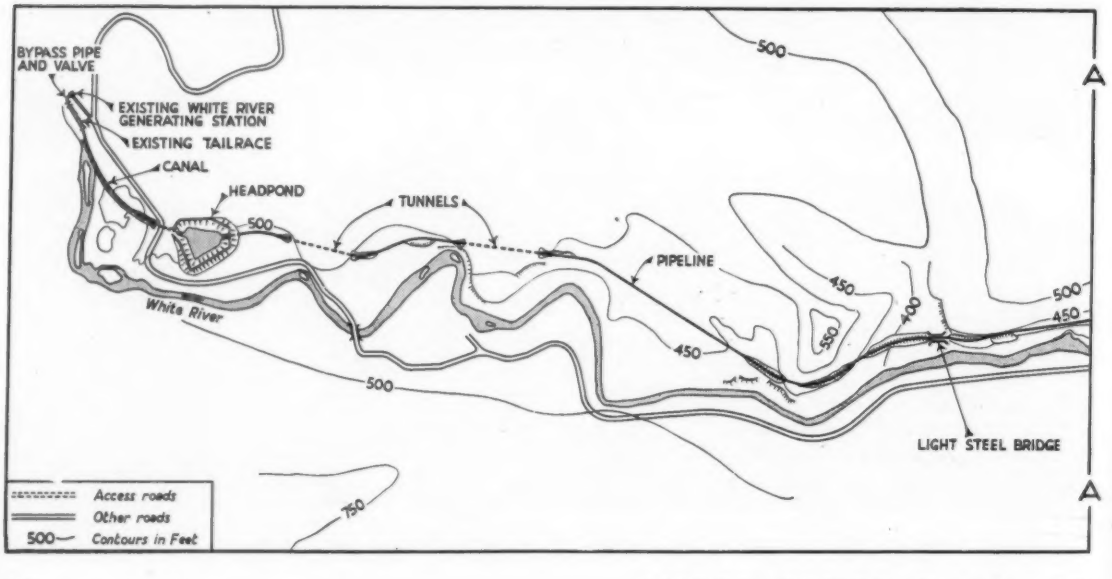
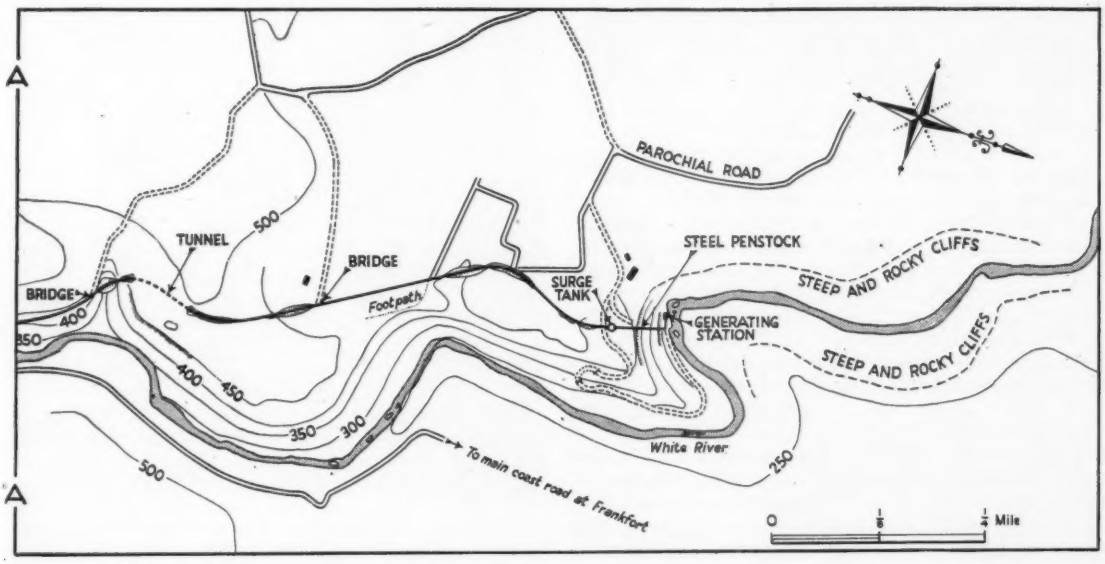


Fig. 5. Bank of headpond, with concrete covering and stone pitching in progress

is apparent in the Moneague where swallow holes abound and where large lakes appear and disappear over the years as the general water table rises and falls. These lakes may rise to a level as much as 200 or 230 ft. higher than the Mount Plenty springs, about five miles distant, and there is said to be some indication of limestone glades leading from the area of lakes to the area of springs.

A somewhat similar situation exists in Iceland, where the flow of the river Sog leading from the lake Thingvallavatn is enormously greater than the small visible inflow to the lake. The Althing, reputed to be the first parliament, is on the margin of this lake. The country is formed of pervious and fissured basalts, tuffs, and other volcanic materials and there is no doubt that most of the flow to the Sog must reach the lake by underground channels. The flow is probably affected to some extent by melting of glaciers



but in any event the perennial flow in the river is remarkably constant at between 2,800 and 3,500 cusecs, with rare deviations to 2,600 and 4,000 cusecs.

Similarly the perennial flow in the White river is fairly well regulated by natural underground storage. There is, of course, a substantial long-term fluctuation in the sense that there are periods of dry years or wet years in the ordinary course of events. There are also spates of some violence during intense tropical rainstorms. Generally speaking, apart from the direct run-off, the average perennial spring flow in White River is of the order of 180 cusecs but there are surface indications that floods of the order of 30,000 cusecs have been experienced.

The river water itself presents an interesting and uncommon problem. The hydro-electric engineer has often to deal with aggressive or, alternatively, undersaturated waters as best he can, but the opposite effect is met with in Jamaica, for the perennial spring waters are usually oversaturated with mineral salts, particularly with calcium carbonate. As it emerges from the springs the water is clear and for all practical purposes innocuous with a *pH* value of about 7·9. As it passes down river over a long series of cascades in the presence of the atmosphere the chemical stability of the water gradually breaks down, the carbonates in solution begin to come into suspension and the turbidity increases until the water has turned to a milky colour in the lower reaches of the river. After the breakdown has begun the carbonate deposits rapidly on most solids in the river, even on plants and shellfish, and a hard continuously growing scale is formed.

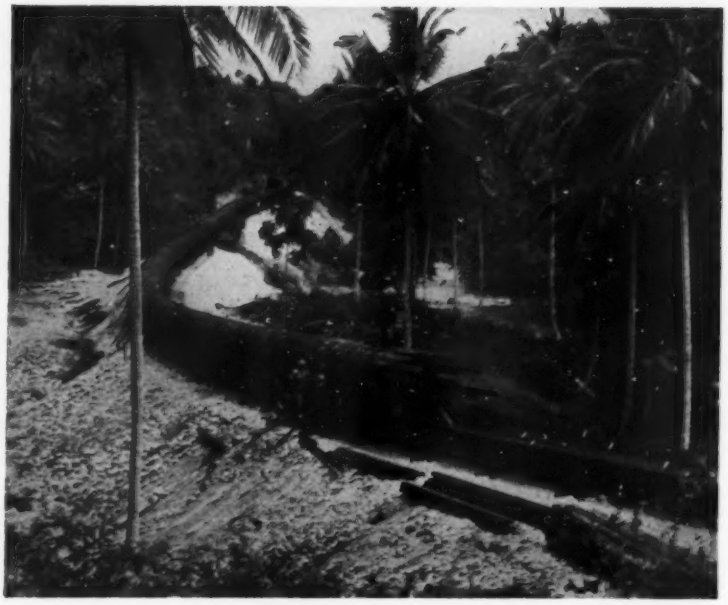


Fig. 6. Woodstave pipe, showing curves and method of construction

An analysis based on the methods suggested by Cox, Baylis, Langelier and others was used to define the chemistry of the water, and confirmation of the conclusions was obtained from information in the possession of the London Metropolitan Water Board. In the analysis a saturation value pH_s may be calculated from the known amounts of the various salts in solution and compared with the measured *pH* value of the water. If the estimated value of pH_s is less than the observed value of *pH*, that is to say a positive value for the saturation index $pH - pH_s$, then the water will tend to deposit its salts in appropriate circumstances. In this case the index is positive and the action is started by agitation and turbulence in the presence of air and a slight loss of carbon dioxide.

Given such circumstances the layout of any hydro-electric development on the White River required very considerable investigation, since any scheme using water in a critical state might quickly become inoperative as a result of the growth of scale on working components. Because of the volume of water involved there could be no question of water treatment by chemicals, and it was not considered reasonable to take the turbine out of service at intervals for cleaning with inhibited acid. In the event a straightforward solution was found since it was noted that the existing upper-river development took in water from a clear section of the river and that there was little evidence of deposition in its tailrace, although deposition was rapid from about half a mile downstream. It was decided therefore to take the water for the lower development, by canal, directly from the tailrace of the upper station, so that the clear water would pass through both schemes either in closed conduits or in canals where there would be little turbulence. With such an arrangement the formation of scale would be greatly reduced.

In addition a bypass at the upper station was included in the scheme so that water might be available if the upper station happened not to be generating.

Layout of Scheme

Because of the fissured and pervious nature of the underlying limestones and marls, Jamaica presents few situations in which a large storage reservoir can be built without difficulty. It was not judged that this could be done economically on the White River, though the underground storage mentioned earlier does partially meet the requirement of regulation of the river flow. Nevertheless some form of pondage is necessary at the intake to a power development and there is a fairly large headpond included in the Lower White River scheme. This is fed by a lined canal leading, as already mentioned, directly from the tailrace of the Upper White River power station. The headpond is formed in a side gully of the White river behind an earthen embankment some 30 ft. high, the water face of which is protected by reinforced-concrete slabs articulated in panels by copper sealing strips. The bottom and sides of the gully lie in largely pervious marl and a decision had to be taken on whether an undue amount of water would be lost. It was noted that the White River itself flows through pervious strata in which there was no clearly defined

water table near the surface. The fact that it flows on the surface at all is in itself something of a phenomenon, and it is apparent that the river has managed to seal its bed largely by the deposition of calcium carbonate, as travertine, since there is very little silt in evidence. It was considered that the pores of the headpond marl would seal themselves likewise in time, and if that process was too slow in developing then silt could be dumped into the water to hasten the action. In the event the rate of loss of water during the first two months after the first filling rapidly fell from about 6½ to 1 cusec, after which time the observations were discontinued.

The canal leading water from the upper station tailrace to the new headpond is likely to be overtopped fairly regularly by floods in the adjacent river, and its side embankments have been pitched to allow this to happen without damage. For the same reason the first length of pressure conduit downstream of the headpond embankment has been constructed as a heavy reinforced-concrete pipe on a bench cut into the hillside. The conduit is then taken into tunnel and continued as a woodstave pipe 6 ft. in diameter until the surge tower is reached. Over the greater part of its length of about 9,500 ft., this relatively low-pressure conduit is situated in difficult steep country, and there are no less than three tunnels and one steel bridge through which the woodstave pipe is carried.

Fig. 7. General view of power station, pipeline and surge tower

Fig. 8. Woodstave pipe leaving the first tunnel

Fig. 9. Power station and tailrace

Although the materials for this pipe were entirely imported from Canada it was both economic and eminently suited to the capacities of Jamaican labour in its erection. Some leakage immediately after erection was inevitable and normal, but the pipe fairly soon staunched itself and the bench formation was affected to a negligible extent.

In some places the driving of the tunnels was hampered by bad ground and the absence of skilled tunnel gangs and suitable equipment, but the work was successfully completed.

Towards the end of its route the woodstave pipe runs along the top of a minor plateau overlooking the deep gorge in which the White River lies. The surge tower is situated on the edge of this gorge and the water is led thence by a steel pipeline 5 ft. in diameter down the precipitous side of the gorge to

a power station built in the bed of the river itself.

The surge tower is a large steel structure standing some 160 ft. high above ground level. The tank itself is formed of riveted steel plate with a hemispherical bottom leading into a riser pipe connected to both the woodstave and steel pipes. It is 30 ft. in diameter and 65 ft. deep, supported on six interbraced stanchions. All parts of the structure were fabricated in Great Britain, fitted and marked before shipment, and erected very successfully on site by a Jamaican contractor. In the early stages of design a tower supported only on an enlarged riser pipe was considered, but although an economical and attractive structure was devised the authors considered it better to concentrate on the perhaps less graceful structure supported on legs, in view of its fundamentally greater resistance to hurricanes and earth tremors, the effect of which can only be predictable within wide limits.

The steel pipeline, which has flanged joints and a number of expansion joints, was also fabricated in Great Britain and erected by the same contractor. The type of joint was selected as being the most appropriate to the very difficult topographical conditions under which the pipe was erected. The pipe is supported on small welded steel saddles with a zinc interleaf between saddle and pipe barrel. Graphite grease was painted on the saddle at the time of erection but no other provision was made for special lubrication of the sliding faces as a normal operation of maintenance.

The power station is situated in the bottom of a steep and narrow gorge and presented difficulties both in construction and in layout, since the site was originally accessible only with difficulty by climbing down the side of the gorge. The narrowness of the river at this point results in a large rise of water level during floods. A zig-zag road with one tunnel on a curve was eventually carried down into the gorge and was successfully negotiated by the heavy articulated vehicle carrying components of plant.

The station accommodates a single machine of 4,750 kW capacity the operation of which is under remote control from the Upper White River Station. It is intended for continuous operation in years of normal run-off although a limited form of working against peak load is possible in dry years by using the pondage in both the lower and upper schemes.

Because of the expected flood rise the generator floor is 35 ft. above normal tail-water level. The turbine basement is watertight for a considerable height but might in extreme conditions be flooded during a major flood, and arrangements have been made to ensure that the station will not be shut down if such a flood were experienced.

The station roof is some 70 ft. above normal tail-water level and is at least 83 ft. above foundation level.

The civil-engineering work was carried out to the design and under the supervision of the consulting engineers. A constructional organisation was set up by the Service Company under their chief civil engineer and surveyor, Mr. E. N. Mais, whose energy and local knowledge were a great encouragement to all concerned.

"La Riva". 1861-1951.

On the occasion of the 90th anniversary of its foundation, this well-known Italian firm specialising in the manufacture of large turbines and pumps has published a commemorative book of great interest to hydraulic engineers. Written by its Managing Director, Guido Ucelli, this fine volume is exceptionally well produced and illustrated by numerous photographs relating to the growth of the company.

The firm was originally founded in 1861 to manufacture steam engines and various rotary machinery; hydraulic equipment, mainly for irrigation purposes, was included in 1875. Alberto Riva appeared among the Directors for the first time in 1879 and the Company became known under his name shortly afterwards. The first turbine was constructed in 1885 and production was soon concentrated in this new field. The then Riva Monneret & Cie. achieved international fame in 1899 by obtaining the contract for the first turbine of the Niagara Falls power station; it is interesting to note that this machine is still in regular service at the present time. The design of the pump for the first Italian hydraulic power storage scheme (1912) led to a detailed investigation of water hammer phenomena, carried out in collaboration with the famous hydraulician Lorenzo Allievi.

At the present time, "La Riva" is one of the largest firms in the world specialising in large custom-built turbines and pumps. The workshops were entirely rebuilt in 1949 and the reviewer has been fortunate enough to see for himself the excellent conditions under which work is now carried out. A new office block was constructed before the last war and extended recently; the accommodation is superior to almost anything found in this country as far as spaciousness, fittings, lighting, and architectural interest are concerned. Among the machine tools installed are several of exceptional size designed and built by "La Riva" itself during periods when the demand for hydraulic machinery was abnormally low.

All types of turbines are being constructed, the largest unit so far being a two-runner Pelton set of 110,000 h.p. for the Premadio power station. A special feature of recent turbines of this type is the straight nozzle in which the needle servo-motor is entirely surrounded by water, thus giving improved flow conditions and a higher efficiency than the conventional bend. Ancillary equipment, such as governors and penstock gates, is also manufactured. Outstanding among pumps supplied is a 23-stage water supply unit to operate against a head of 2,700 ft., and a 40,000 h.p. storage pump for a head of 2,000 ft. The hydraulic laboratory is at present being considerably enlarged in view of the importance attached to research and development; full facilities for model testing and cavitation investigations will be available and a wind tunnel for air testing of runners and other components is projected.

One of the interesting features of "La Riva," reflecting to some extent a tendency typical of Italian industry, is the wide range of social and cultural activities sponsored by the management. Among these, the visit of engineers and workshop staff to power stations equipped with Riva turbines plays an important part in producing pride in good workmanship and that spirit of common effort which is reflected in the large number of long-service medals held by the employees of this company.

Civil and Mechanical-Engineering Aspects of Hydro-Power Development—II

The second of four post-graduate lectures given by P. W. Seewer, Consulting Engineer to the English Electric Co. Ltd., to the Hydro-Power Course at the Imperial College of Science and Technology, City and Guilds College, South Kensington, London

BEFORE beginning this second lecture I feel in duty bound to answer a little more thoroughly several questions put to me after the first lecture.

(1) One question was, which are the principal considerations for the selection of the specific speed and the speed in r.p.m. of a plant, and what are the deciding factors in bordering cases whether impulse, reaction-propeller or feathering-propeller plant should be installed?

ANSWER: Given the quantity of water, the head and the output asked for, the specific-speed chart (Fig. 6) shows what specific speed can be chosen from the numerous plants in operation. If the turbines are to drive electric generators the resulting speed must of course correspond to the next synchronous speed for machines producing alternating current and to the correct speed physically possible for direct-current generators. Intensive and sustained collaboration with the electrical designers is essential from the start; this is true, not only for the machinery but for the arrangements of the plant as a whole, including pipelines and valves, as well as the transformers and switchgear, exciters, protective devices, and all other electrical gear.

But the speed finally selected depends also on the result of intensive tests and research, judicious choice of material and the physical and chemical properties of the water. The runaway speed, which can attain several times the normal synchronous speed, is also a most important consideration in respect to the maximum permissible peripheral speeds, for both the turbines and generators.

The chart, therefore, is very useful for guidance for first selection of the speed, but all the other factors mentioned must be taken into careful account, inclusive of proper safeguarding against cavitation.

The selection of the type of plant is fairly fixed by the fact that impulse (Pelton) turbines can only be built efficiently for a maximum specific speed up to about 30 (metric) per jet, high-pressure reaction turbines up to about 100, medium-pressure ones up to about 300 to 350.

For low and very low pressure-heads propeller or feathering-propeller turbines are the correct types to be installed when specific speeds up to 900 and more can be adopted. The expression specific speed introduced by Professor Camerar is the speed at which a turbine would operate if delivering the unit power under the unit head. It is simply a convenient factor for comparing the various capacities of turbines, their heads and speeds.

(2) Another enquiry was about the speed at which valves or turbines could be closed.

ANSWER: This is entirely a question of hydrodynamics, and is dependent on the effect the inertia of the moving water column produced when it is stopped in a certain time at a certain rate. Various experts like Professor Allievi, Professor Neeser, Professor Gaden and others have published their mathematical analyses and experimental results on the degree of waterhammer as a function of time, following on closure or opening of a turbine or valve. Their findings correspond very closely to the results observed in the field in numerous plants.

The opening and closing times must be selected and calculated both to exclude a detrimental waterhammer in the pipelines and to avoid harmonic fluctuations in pressure in both the positive and negative directions, so as to avoid accidents. Negative pressure can also be dangerous.

(3) Another question which I thought of sufficient general interest was, what decides the turbine to be of the feathering-propeller or fixed-vane propeller type?

ANSWER: This is determined by technical and economic considerations, as to whether the turbine should have high efficiencies, not only at optimum load, say $\frac{7}{8}$ or $\frac{3}{4}$ full load, but also at part load, and for changing heads; in other words, feathering-propeller types are essential to increase and broaden the range of high efficiency for very wide variations in output and head.

In my centenary lecture in June, 1947, I stated that it is possible to build feathering-propeller turbines up to about 200 ft. pressure or more; this figure has indeed since been slightly exceeded, due to intense research and tests. For block-load plants in which both load and head remain substantially steady all the time, fixed-vane propellers are satisfactory, but wherever load and head are subject to frequent fluctuations the higher cost of feathering-propeller sets is quickly compensated by the higher efficiencies thus obtainable.

Prospects for Engineers

The prospects for men entering this branch of engineering are wide and far reaching. According to his propensities he can either enter the promoting field, the hydrographic survey, geologic or topographic survey, the civil and engineering branch for the establishment of the necessary dams, intake and defence works, tunnels, surge tanks, pipelines, access roads, power houses and tailraces, or he can enter the field as a prospective designer, which is of necessity highly specialised, and it demands years of technical training and practical experience so as to enable him to estab-

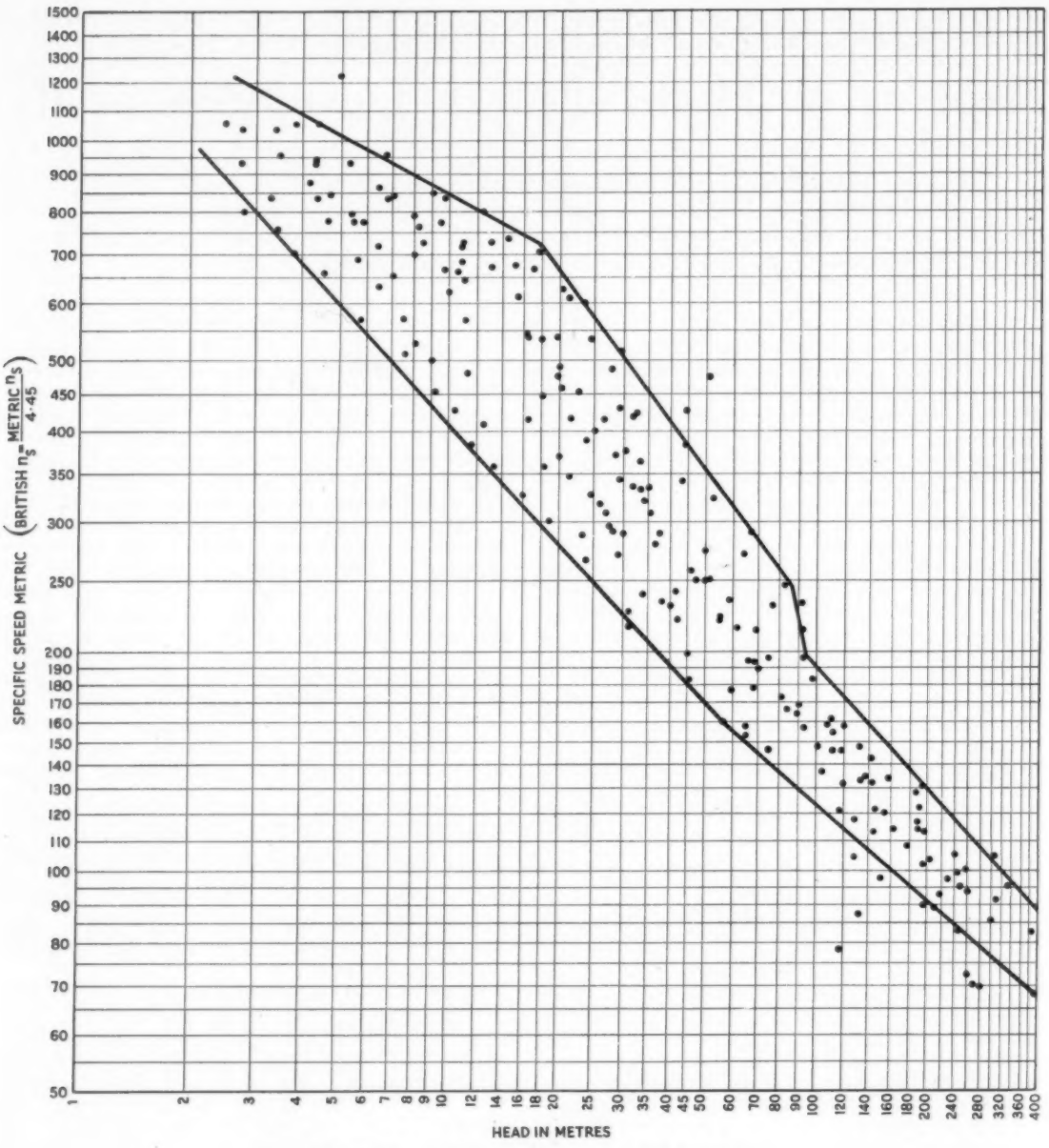


Fig. 6. Specific speeds of plants in operation

lish the most appropriate type, size and form of plant best suited to cover the essential requirements of the promoting authority.

Apart from design one of the most interesting fields is research and test work, both operative and technological, which generally can be entered with profit only after a stage in the design and drawing offices. An important branch also is to train in the economic studies of alternative technical layouts, quantities of work, weights and prices thereto, detailing of the plant as such, for sluices, valves and regulating apparatus including all automatic features. For those having the necessary propensities scientific salesmanship in this branch of engineering presents interesting openings. He can also become an expert on erections with prospects of becoming a resident engineer after acquiring the necessary experience in the field, demanding considerable aptitude to organisation and handling of men and programming of work. He can also enter the productive side, including all materials and their machine work, shop assembly and tests, apart from welding, annealing and all other treatments. An interesting opening is presented by the public services who look after the operation, control, maintenance and general supervision of the plants inclusive of the distribution.

There are many other collaborating departments as, for example, those dealing with pipelines, lubricat-

ing and cooling plants, cranes and other handling gear, dewatering plants, spare parts, etc., all essential for the successful establishment of the schemes and the continuous uninterrupted operation of hydro plants. Many years of experience prove that proper organisation of all this collaboration by one firm spares a great deal of work and delay in the completion of the plants.

Technical Qualifications

The technical qualifications must consist of a thorough training in a technical school or university to acquaint oneself with the purpose, form and operation of all appurtenances of the plant and machinery, the establishment of the necessary type of material, weights and particularly stresses, the performances to expect and to be guaranteed and their relation to speed, efficiencies, wear and tear, and general operational characteristics. The qualifications must also include a thorough knowledge of the technological properties of materials and their adequacy for the purpose they are to fulfil.

Promoting Authorities in this Country

The Water Power Resources Committee (1921), the Weir Committee (1925), the McGowan Committee (1936), the Hilary Committee (1938), besides several Parliamentary Committees and Commissions, have extensively investigated hydro-electric promotions in this country. The chief authority in this country is the British Electricity Authority, which has compiled, apart from other committees, a great number of valuable statistics and other general information giving broad lines of guidance for the establishment and execution of hydro-electric schemes. In the British Empire the authority for the present and future undertakings in this field is mostly vested in Public Works Departments as one of the Government services which computes the necessary data for the power available and its marketing, computing the information both hydrographic and geological, apart from the economic factor and distribution.

Apart from public undertakings, many private companies are dealing with the establishment and utilisation of hydraulic power for their own purposes, mostly concentrated in electro-chemical and electro-metallurgical industries and power requirements of every description, such as factories, pulp mills for paper industry, spinning, pumping for water supply, sewage, and light and power for domestic purposes.

The theoretical training in either technical universities or technical schools should always be combined with thorough apprenticeship in workshop, drawing office, design office, and in a technical laboratory to acquire the necessary basic practical experience, also in operating machinery, producing methods, and strength of material, and it is recommended to peruse technical literature which is mostly available in the libraries of the technical colleges and universities or the Institutions of Civil, Mechanical and Electrical Engineers.

The electrical field is not essentially different as far as the machinery is concerned from the one of general electrical engineering, but the transmission and distribution of power, including all protective gear, merits particular attention.

Rome University Scientific Publications

A number of papers have recently been received from the University of Rome, written by members of the staff of its Hydraulic Engineering Department. They are reprints from "L'Acqua," a periodical almost unobtainable in this country, and cover various constructional and hydro-dynamic matters connected with hydraulic structures. Details and a brief summary of their contents are given below.

No. 13. Sulla stabilità della sabbia sotto l'azione di un flusso d'acqua ascendente (The stability of sand in a rising stream of water), by L. Canali, 1950, 12 pp. Measurement of the flow and pressure drop in a cylindrical sand filter and determination of the critical velocity at which the bed becomes fluid. Good general agreement with theory but critical velocity low by 10—20 per cent. due to the method of estimating the porosity of the sample.

No. 15. Modello idraulico per lo studio del moto di filtrazione attraverso fondazioni permeabili (A hydraulic model for the investigation of filtration through permeable soils), by L. Canali, 1950, 10 pp. Study of leakage underneath a dam, using a two-dimensional glass-fronted model with numerous pressure tappings.

No. 17. Gli aeranti nei calcestruzzi (Air entraining media for concrete), by C. Lotti, 1950, 11 pp. A review of previous experimental work on the properties of aerated concrete.

No. 18. Il moto dei miscugli di aria e di acqua in condotte in pressione (The movement of air-water mixtures in pipes under pressure), by V. Mongiardini, 1951, 15 pp. Experimental results for Reynolds Numbers between 10 000 and 50 000 and air contents up to 30 per cent. by volume.

No. 19. Attivazione elettrica del prosciugamento e del consolidamento dei terreni (Electrical drainage and consolidation of the soil), by L. Canali, 1951, 10 pp. A brief review of the basic theory and details of recent tests carried out in Switzerland.

No. 20. Gli aeranti nei calcestruzzi. Recenti sviluppi del loro impiego (Air entraining media for concrete. Recent developments in their application), by C. Lotti, 1951, 9 pp. Further details of tests by other workers.

No. 21. Alcune osservazioni sullo stato di sollecitazione delle gallerie in pressione (Notes on the stresses in pressure galleries), by F. Arredi, 1951, 8 pp. Theoretical investigation of the stress distribution in the concrete lining, a rock layer whose elasticity varies radially due to grout injections, and the remainder of the rock.

Automatic Control Instruments

Sunvic Controls Limited staged an interesting film recently to show how control of flow, liquid level and so on has gradually progressed from the crude practices of former times into the highly scientific and accurate operation that it is today. Three types of control were considered, *i.e.* proportional, integral and derivative, and the improvement in the precision of control by these successive stages was clearly demonstrated with the aid of diagrams and a working model. The Sunvic concern manufacture the Nullmatic liquid-level transmitter, various forms of flow controllers, valve positioners and other industrial control instruments.

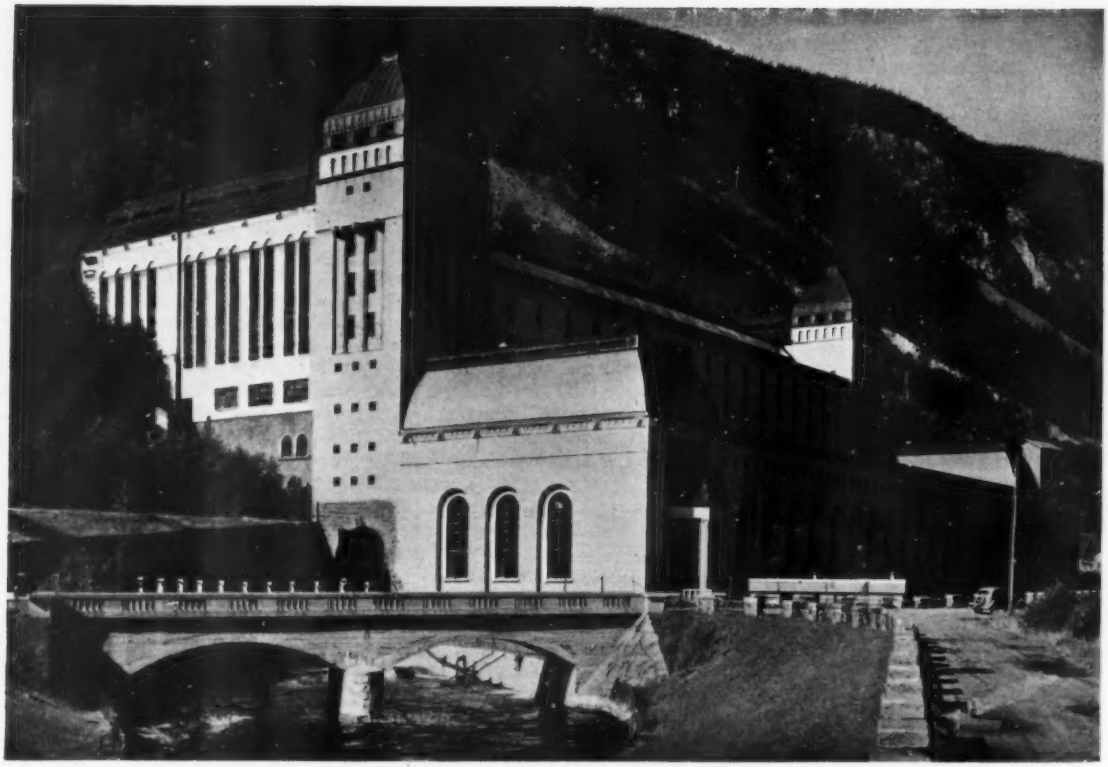


Fig. 1. One of the artificial fertiliser factories at Rjukan, driven by water power

Development of Hydro-Electric Power in Norway

Sigurd Brinch and Kristen Friis give a historical sketch of the development of water power in Norway, and outline the main features of the Tyssefaldene and the Raanaasfoss schemes. Although these are not new stations they are considered to be representative of Norwegian high-head and low-head developments respectively.

THE earliest use made of water power in Norway has probably been for driving the farmers' small flourmills with a "tub-wheel" (kvern-kall). This tub-wheel, as will be seen from Fig. 2, contains the embryo of our modern turbines. In its action it is an impulse wheel (Pelton), but with its inclined vanes it has a leaning towards the Francis, and if the vanes were made movable it would emerge as a modern Kaplan.

Where there was a stream running on or near the farm, every farmer had his own mill. This was partly because the Norwegians have always been strictly individualistic, and partly from the practical reason that in many of the small streams where these mills were installed, the periods when sufficient water was available were usually restricted to the spring, when the snow melted, and to the rainy season in the autumn. Some of these mills are still in use in remote places.

Later on came the sawmills and then wood-pulp factories, the latter being driven by more modern turbines coupled direct to the grindstones.

The first hydro-electric plants were built in the late years of the nineteenth century, and the first city to be lit by electricity produced in this way was Hammerfest at 70° North.

The first hydro-electric plant of sizable dimensions was finished shortly after the year 1900 on our largest river, the Glomma, at Kykkelsrud, for an installation of 45,000 h.p., something unprecedented in those days.

Fig. 2. Primitive "tub-wheel" as used for farmers' flourmills

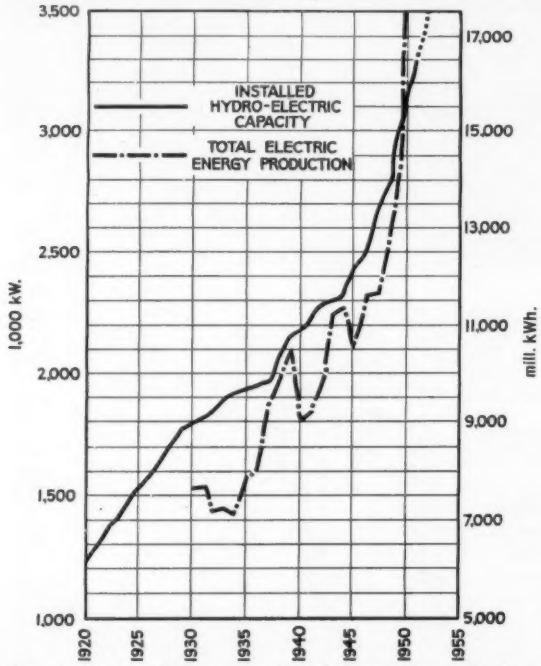


Fig. 3. Norwegian hydro-electric capacity and electricity production

A few years later the Birkeland-Eyde process of extracting nitrogen from the air by means of an electric arc was passing its experimental stages, and three hydro-electric power plants were built for the commercial production of artificial fertilisers, one at Notodden for 30,000 kW and two at Rjukan (Fig. 1) with a total capacity of 260,000 kW.

Today Norsk Hydroelektrisk Kvelstofaktieselskab —"Hydro" for short—has at its disposal water power to a capacity of 400,000 kW.

Hydro-electric power now changed from the exceptional to the normal, and private companies and communities started to build power stations for distribution of electric current to the public at large, together with a continued development of hydro-electric schemes for the chemical, metallurgical and other industries.

The curve in Fig. 3 shows the rise in production from the beginning of this century up to today. If we sum up the water power available from units over 500 kW, it is estimated that ultimately 12 million kW can be harnessed, this amount of energy being available throughout the year. The better part of this potential power is situated along the west coast of southern Norway, as is only to be expected when we examine the configuration of the country.

A cross section of the middle part of southern Norway, Fig. 4, shows the marked contrast between the configuration of the east and the west—the east with its gentle slopes against the steepness of the west coast. In the east we have the large catchment areas with comparatively low heads, seldom over 150 m., against the restricted catchment areas on the west coast, but with heads up to 1,000 m. The west coast also has the advantage of a heavier precipitation, amounting in some places to more than 3,000 mm. per annum, whereas in the east it varies from 300 to 1,200 mm., including snow measured as its water equivalent.

A Typical High-Head Plant

As an example of the west coast high-head plants we have chosen Tyssefaldene in Hardanger (Fig. 5). It was the first high-head plant built in Norway, and second only in Europe to "Brusio" in Switzerland, which was finished a few months earlier.

The hydro-electric power plant at Tyssedal was built in 1906-8 to supply the Alby United Carbide Factories at Odda with some 25,000 h.p. A total head of 415 m. from lake Ringedals down to sea level was utilised.

When this station was designed, most of the meteorological stations on the west coast of Norway were placed near sea level, and did not give a correct picture of the precipitation over the major extent of the catchment area lying at an altitude of from 1,000 to 1,500 m. Thus, what was at the time estimated to yield some 50,000 h.p. has later turned out to be capable of 125,000 h.p. All but one of the streams from the little lakes spread over a catchment area of 406 sq. km. empty themselves into lake Ringedals,

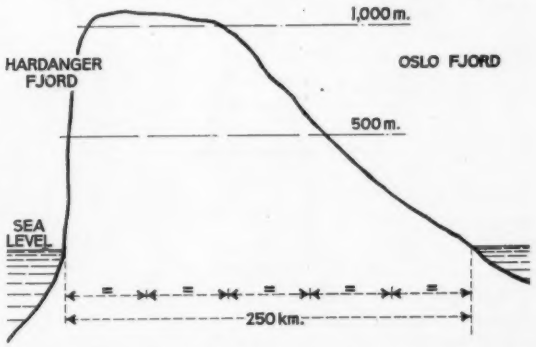


Fig. 4. Typical west-to-east cross-section through Norway

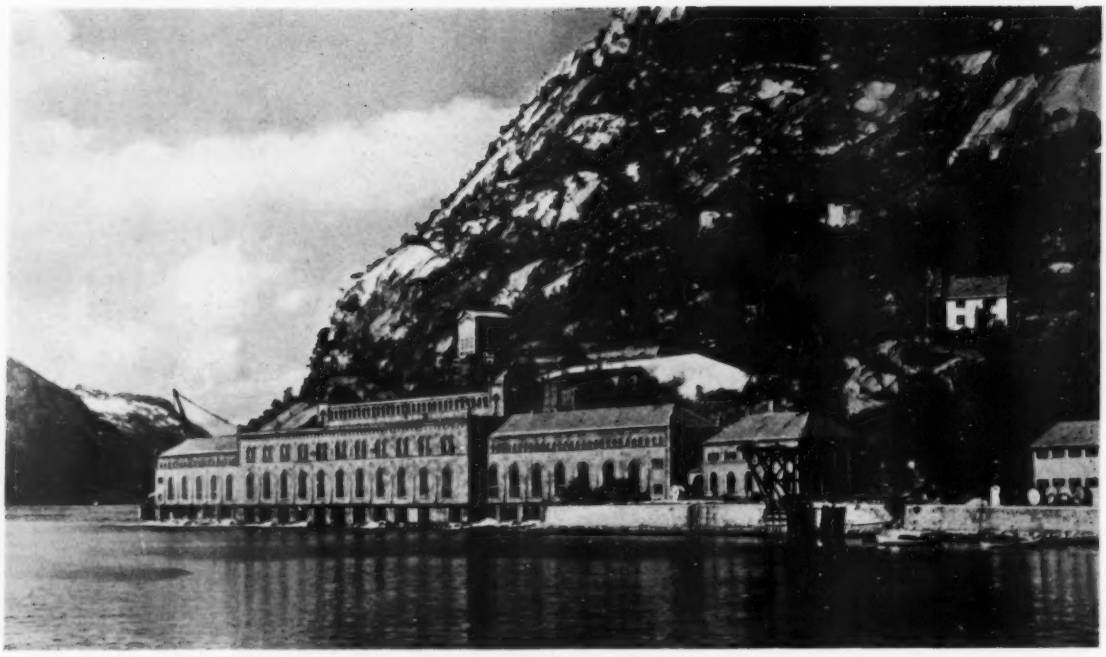


Fig. 5. A general view of Tyssefaldene power station

which makes an ideal storage basin with a surface area of 5·6 sq. km.

Both the completed and the projected portions of the Tyssefaldene scheme are shown diagrammatically in Fig. 6. In connection with the first instalment a tunnel through the rock barrier at the outlet tapped the lake 20 m. below its natural level. In addition a low dam was built, and by means of these arrangements a storage basin of 122 million cu.m. was made available.

From below this lake a tunnel in the hillside, 3,420 m. long, took the water to a forebay on the steep mountain side 415 m. above the Hardangerfjord.

Two pipelines 740 m. in length and from 1·2 to

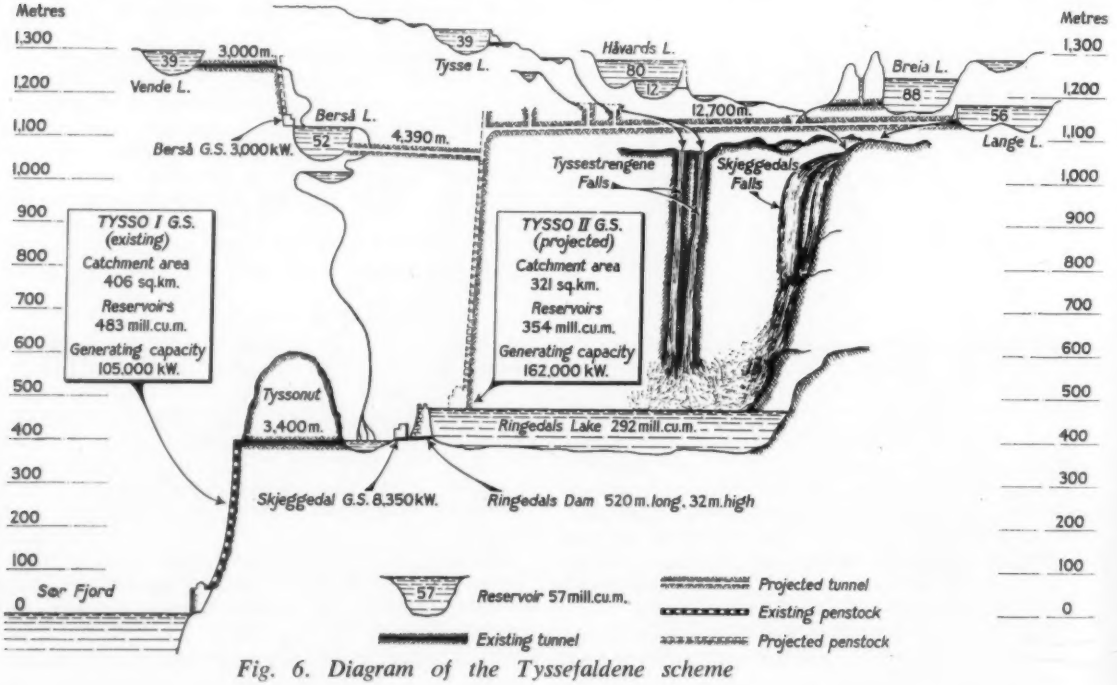


Fig. 6. Diagram of the Tyssefaldene scheme

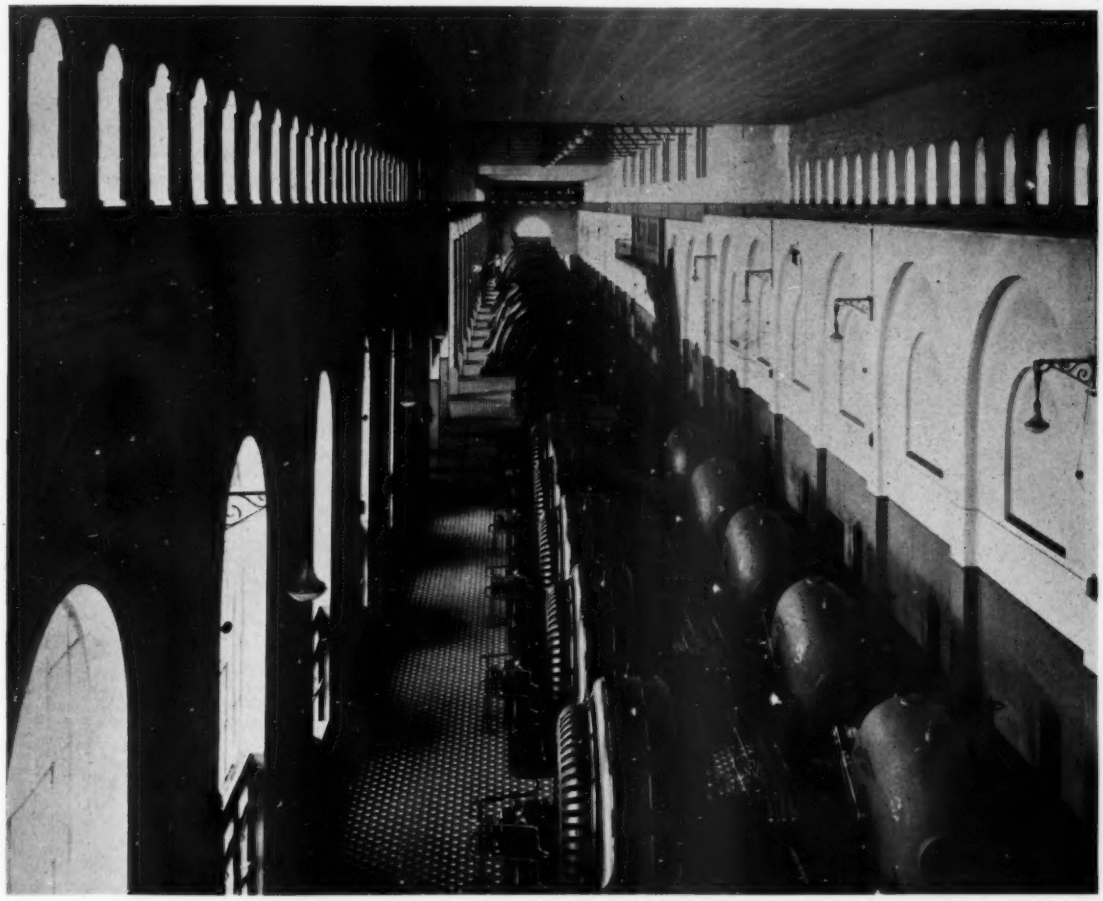


Fig. 7. Interior of Tyssefaldene station showing some of the original machines in the foreground

0·95 m. in diameter carried the water down to the power station on the shore of the fjord. The installation consisted of seven 5,000 h.p. Pelton turbines driving three-phase 25-cycle alternators generating at 12,000 V and delivering direct to the transmission lines, which extend 6·6 km. along the fjord to the factories at Odda. Parts of the route were unsafe by reason of avalanches of stone and ice, and over these stretches the transmission lines were run in a tunnel.

As experience was gained as to the real annual flow of water available, the power station was greatly enlarged during the years 1910-1916, when the turbine installation was increased to 145,000 h.p. and the original carbide works were supplemented by other industries such as cyanamid, zinc and aluminium works.

Fig. 8. Site of Raanaasfos station before development, showing timber being floated down the river

In conjunction with the increase in the power produced, other works were put in hand. A second tunnel was required and three more pipelines were laid. The storage capacity had to be enlarged, and to this end a new dam at the outlet of lake Ringedals was built. This is a straight gravity dam 33 m. high with a length of 500 m., increasing the storage capacity of this lake to 290 million cu.m. Other lakes in the mountains were also regulated, bringing the total storage capacity up to 490 million cu.m.

The power station at Tyssedal

Fig. 9. General view of Raanaasfos station, showing the roller gate

gives a typical example of the evolution of turbines and electric equipment during the period under review, the unit sizes having grown from the original 5,000 h.p. in 1908 to 18,000 h.p. in 1926. The sets installed in the years 1912-1916 were as follows:

1 unit of 10,000 h.p.
1 unit of 13,500 h.p.
4 units of 15,200 h.p.
2 units of 18,000 h.p.

Plans have been worked out and some progress has been made towards the next step — the construction of a "Tysse II" which will utilise the possibilities of power production above the present plant between the altitudes of 1,150 and 465 m. above sea level. These proposals will be noted in the schematic diagram Fig. 6. A tunnel round the east and north side of lake Ringedals will take in all the streams now running to waste between these altitudes and use them to produce some 155,000 h.p. before running into the storage reservoir of the lower plant. The scheme so planned will be carried out according to requirements.

As this diversion will impair the beauty of two famous waterfalls, "Tyssestrengene" and "Skjeggedalsfoss," lake Ringedals will lose some of its tourist attraction; but then, we suppose tourists will have to be educated to admire the 155,000 h.p. instead!

A Typical Low-Head Plant

As a low-head power plant from eastern Norway we have chosen Raanaasfoss on the river Glomma (Figs. 9 to 13). Whereas Tysso had a catchment area of some 420 sq.km. we have here nearly 40,000 sq.km.

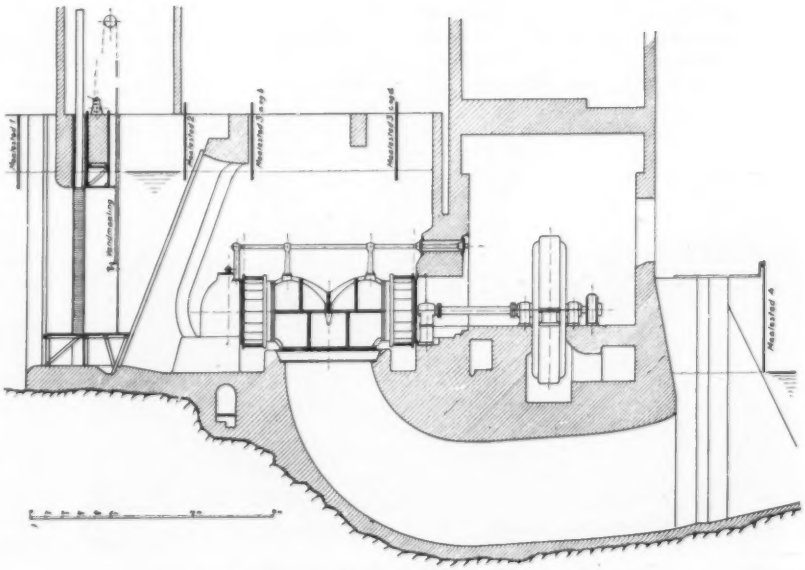


Fig. 10. Cross-section through Raanaasfos station

The minimum regulated flow of water is at present 275 cu.m. per sec. but there is a possibility of increasing this to 400 cu.m. per sec.

A head of 14 m.—between 118 and 104 m. above sea level—is available so long as the flow of water keeps below say 5-600 cu.m. per sec. In full flood the head is reduced to 10 m.—between 120 and 110 m.—as power plants farther up the river limit the rise of the backwater to 120 m. When building a power station on this part of the river, there are two problems of major importance to take into consideration apart from the power plant proper, viz: to cope with flood water, amounting to some 4,000 cu.m. per sec., and to allow for the passage of from 8 to 12 million pieces of lumber which are floated down the river in the spring and early summer (Fig. 8), and the power plant must be prepared to deal with up to a round million of these in 24 hours, as the progress of the floating is very irregular.

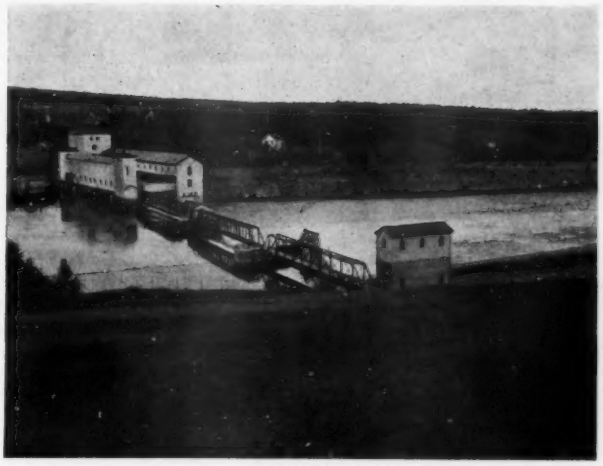


Fig. 11. Another view of Raanaasfos from the opposite side of the river

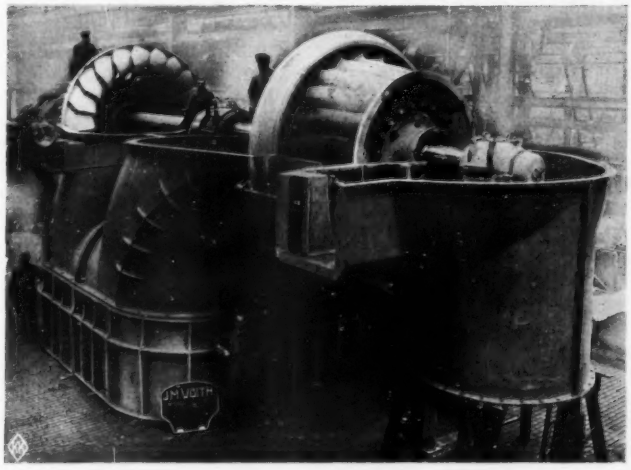


Fig. 12. Raanaasfos No. 4 turbine during erection at the makers' works

The fall utilised at Raanaasfoss is made up of a series of rapids stretching as far as 15 km. up the river above the power station and dam.

To take care of the maximum flood water, the spillway, apart from six 2 × 4 m. ground sluices, covers the whole length of the dam and is divided into three sections. One of these consists of a roller weir 45 m. long and 6·5 m. high (Fig. 9) which can be lifted clear of the water, and the others consist of two sector gates, each 50 m. long and 3·75 m. high, which can be lowered into the main body of the dam. The sector gates (see Fig. 13) serve a dual purpose as they also afford a passage for the main bulk of the lumber. Normally the tops of the gates are flush with the top of the dam, but they can be moved to any desired position by means of a combined hydraulic and compressed-air system. As long as there is sufficient water, the lumber is passed over the sector gates, but when the water is getting scarce the lumber is passed through a lumber flume, 800 m. long, cut in the hillside opposite the power station. This arrangement, however, has very seldom been used.

The power station is equipped for an ultimate regulated constant flow of water of 400 cu.m. per sec., and contains six units having a total capacity of 72,000 kVA. The turbines were ordered for a capacity of 12,000 h.p. at a net head of 12·25 m. and 107 r.p.m., but as they were required to maintain the same capacity at the decreased head of 10 m. under flood conditions, they were constructed for a maximum consumption of 92 cu.m. per sec. They are horizontal twin Francis turbines placed in separate open concrete chambers and direct coupled through watertight partitions to 12,000 kVA 7,500 V 50 cycle generators.

For transmission to different parts of the supply area and for interconnection with other power systems, the voltage is stepped

(Continued on page 429)

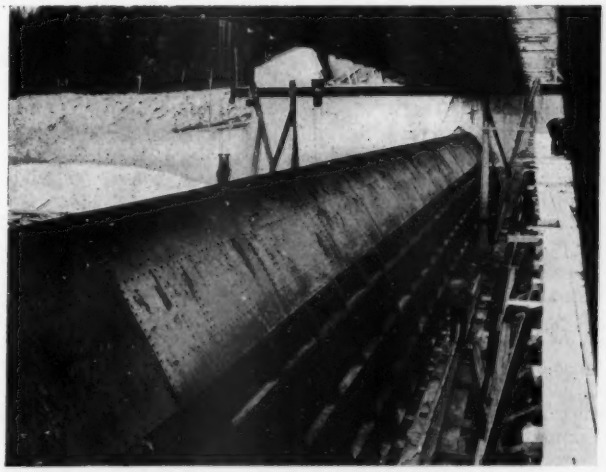


Fig. 13. Sector gate during construction

Vibrated Concrete

At the 114th Annual Meeting of the British Association for the Advancement of Science, held in Belfast in September of this year, the principal Paper of interest to hydro-electric engineers was that on "Some Recent Developments in Concrete Technology", presented to Section G (Engineering) by D. A. Stewart, A.M.I.C.E. Extracts from the paper are given below.

THE first half of the century has witnessed a rapid development in the practices relating to the manufacture and placing of concrete, particularly in the field of civil engineering. In particular the development of mechanisation has made it necessary to make a careful and analytical study of mix design, with the object of substituting a scientific method for the existing empirical one.

Mix Design

Many attempts have been made to design mixes on mathematical lines and probably as many empirical curves have been produced which purport to give the answer by way of the best grading to the engineer seeking the mix for the job. Most of these attempts have been related to manual placing, in which the compacting effort per unit volume of concrete is small compared with modern vibrational treatment and in no way so thorough. Manually-placed concrete has to be of such a nature that a pile of freshly mixed material, when given two or three light strokes with a trowel, will develop a smooth, well-filled and glistening surface. The required effect is readily produced by the use of a rich mix containing coarse aggregate of a small maximum size, $\frac{3}{4}$ in. or $\frac{3}{8}$ in., and a liberal supply of sand and water.

Concrete does not possess those well defined characteristics in its freshly mixed state which allow of a simple classification; features such as "workability," "mobility" and "fluidity" defy exact definition, each aspect merging into the other to some extent. For instance, a harsh lean gap-graded concrete may compact very readily under the influence of the vibration imparted to it by the skip in which it is being conveyed, but on reaching the placing point it is found to be quite unworkable and immobile because of the ease with which it has already compacted. If, however, vibration is applied once more, the concrete will flow quite readily from the skip into the formwork. Some hint is given here that the abovementioned characteristics must be considered in relation to the method of handling and compacting the concrete, although it has been maintained by the Road Research Laboratory that workability is an intrinsic quality of the concrete which is defined as the "useful internal work necessary to prodce full compaction." Others, including the author, have been forced to the conclusion that workability, thus defined, refers chiefly to the compactability of the concrete, whereas the term workability might be expected to cover both mobility and fluidity. It is a little difficult to distinguish between these two qualities and so the following approximate definitions are given. Mobility is equivalent to a turbulent flow in a liquid, *i.e.*, the concrete does not move forward by one layer sliding over the adjacent layer. Fluidity is equivalent to free flow where one layer slides over the adjacent layer, *i.e.*, the rate of flow at any section is proportional to the velocity gradient. As will be observed from these definitions, fluidity in concrete is hardly possible mechanically owing to particle size and distribution, and hence mobility is of more practical interest to the engineer.

Those who have observed the behaviour of concrete in the process of compaction will have noted that the initial settlement or downward movement of the mix is rapid, but that the movement quickly slows up as the voids in the mass are reduced. This suggests that both mobility and fluidity of concrete are dependent upon the degree of separation of the particles of which the mix is formed and that, where mobility is required, measures must be taken to maintain a suitable degree of separation. This may be done in one of two ways, the alternatives depending upon the method of handling the concrete after mixing and during placing. Consideration of the post-curing behaviour of the concrete will be omitted for the moment. Flow may be encouraged by maintaining the separated condition of the coarse particles in the mix from one another. This may be achieved by introducing into the particle assembly material in the coarse aggregate group of a size capable of causing "interference." The quantity and size of this "interference" material must be correctly gauged so that, while decreasing the total voids, the individual void size will not be reduced to an extent which will inhibit the free passage of the larger particles in the fine aggregates, as the failure of the fine aggregate to act as a filler will cause an increased demand for cement paste. Alternatively, the coarse particles in the mix may be adequately separated in the semi-compacted state by the application of vibration. Thus concrete may be expected to flow readily, provided that the intensity of vibration is sufficient to produce dilatancy in the system of particles and that the effective maximum size of the coarse aggregate allows these aggregates to move freely within the formwork; that is to say, the correct size relationship exists between coarser particles and the spacing of the opposing shutters.

The foregoing consideration indicates that concretes may be divided into two classes, the first of which is characterised by possessing within itself, by virtue of the aggregate grading, the essential requirements of mobility and fluidity, but lacking to a varying degree the quality of stability on compaction. The other class of mix relies upon external stimulation in the form of appreciable vibration to provide it with its mobility and fluidity.

This class of concrete is highly compactable and, once compacted, develops an extremely rigid internal structure of interlocked particles. What is particularly

interesting about this view of the subject is that it illustrates the use to which the two principal systems of grading may be put. These systems are generally known as continuous and gap grading. The continuous-grading systems makes use of all the nominal particle sizes from the largest to the smallest and may cover the range from 6 in. to British Standard sieve No. 200. Gap grading, as the term implies, is characterised by the absence of certain nominal sizes, specially chosen so as to reduce interference to a minimum. Fig. 1 shows two grading curves for natural river gravels; that marked *A* is continuous, while *B* is typical of a gap grading. The essential difference between concretes made from these two gradings is that the use of continuous grading does not permit the mix to be predetermined mathematically on a basis of knowledge of the physical characteristics of the individual and collective aggregates, while a gap-graded concrete can be very closely designed as regard proportions, water : cement ratio, and workability, once the necessary tests have been made to determine the design factors of the coarse and fine aggregates.

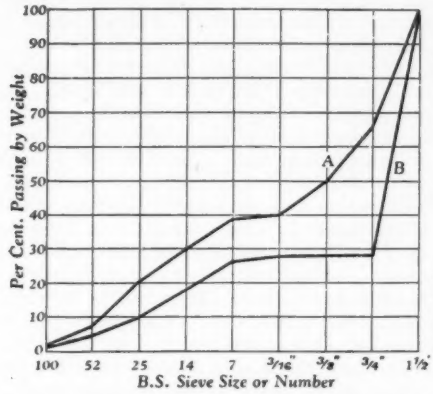


Fig. 1 (left). Grading curves for natural river gravels

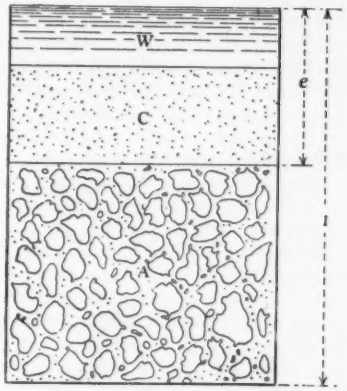


Fig. 2 (right). Diagram showing Void Ratio which must be occupied by cement paste

The coarse and fine aggregates having been selected and tested in regard to their physical and chemical characteristics, the engineer may proceed to design his mix to meet the mixing and placing conditions. His mix design should be based on the assumption that the concrete will be fully compacted and hence unit volume of concrete may be depicted thus. Consider a vessel, Fig. 2, the volume of which is to be regarded as unity, filled, under gentle vibration, with combined coarse and fine aggregate, the upper surface of which is just level with the top edge of the container. Imagine these aggregates reduced to a liquid state so that they collapse, getting rid of all the contained air voids and filling that portion of the container marked A. The space represented by the depth *e*, divided by the volume of the container 1, gives a value called the Void Ratio. For a fully-compacted concrete which will not develop segregation, this space must be occupied by cement paste, the cement and water being mixed in the appropriate proportions to give a required strength.

For the purpose of our analysis, consider the cement to be melted down to the voidless volume C, in the diagram; then, the liquid part of the paste occupies the space W. Now we have all the ingredients of the concrete separate, but fully compacted—the condition the concrete will attain under the influence of vibration. AC and W are absolute volumes. Let the specific gravity of the three ingredients be as follows:—

d_a = mean specific gravity of the combined aggregates (sand and stone);

d_c = specific gravity of the cement;

d_w = specific gravity of the water, usually taken as 1.

The bulk density of the combined aggregates can now be expressed as

$$\frac{(1-e)d_a}{1} = \frac{A\,d_a}{A+C+W} \quad . \quad . \quad . \quad (1)$$

Since this is the bulk density of unit volume of material, it will be referred to as the specific bulk density (Sp. B.D.).

Specific Bulk Density

In designing a mix we have to consider three aspects of the matter and these can be set out as follows and then combined in equation (1):

$y = \frac{A}{C}$ ratio, on which depends the cost of the mix;

$x = \frac{W}{C}$ ratio, on which largely depends the strength of the cured concrete.

y may be expressed as $\frac{A\,d_a}{C\,d_c}$ or $A\,d_a = y\,C\,d_c$;

x may be expressed as $\frac{W\,x\,l}{C\,d_c}$ or $W = C\,d_c$.

The equation for the Sp. B.D. can be written in the form:

$$\text{Sp. B.D.} = \frac{C\,d_c\,y}{\frac{C\,d_c\,y}{d_a} + \frac{C\,d_c}{d_c} + \frac{x\,C\,d_c}{1}} \quad . \quad . \quad . \quad . \quad (2)$$

$$= \frac{C\,d_c}{C\,d_c}\left(\frac{y}{\frac{y}{d_a} + \frac{1}{d_c} + x}\right)$$

and

$$\frac{y}{\frac{y}{d_a} + \frac{1}{d_c} + x} \quad . \quad . \quad . \quad . \quad (3)$$

The theoretical quantities calculated by this method require some adjustment in the field because of loss of sand in the mixer and loss of mortar through joints in the shuttering during placing, where vibration is used. The additional quantity of sand which it will be necessary to add must depend upon the mixer performance and on the accuracy and firmness of the shuttering. As a rule, an increase of 10 to 15 per cent. on the calculated sand content is adequate. Thus, if the theoretical quantity of sand is 25 per cent. of the combined aggregates, the actual mix should be worked out on a basis of 27 per cent.

Effect of Reinforcement

The presence of an appreciable percentage of reinforcement has an interesting effect upon the design of the mix. Where the bars are closely spaced, as they may be when vibration is used, the volume of the bars must be considered as coarse aggregate. The close spacing of the bars precludes the coarse gap-graded aggregate from entering an area roughly bounded by the perimeter of either bar group; so it is evident that the volume of coarse aggregate must be reduced by the volume occupied by the bars. The fine aggregate therefore increases as a percentage of the combined aggregates in the mix as delivered from the mixer. The following example will illustrate this particular design consideration.

Suppose that the mix, as determined from the known characteristics of the aggregates, the required crushing strength and aggregate : cement ratio is 112 lb. cement, 220 lb. sand, and 580 lb. stone (dry weights). This mix is to be compacted into a beam of 30 in. depth and 14 in. width having three layers of three $1\frac{1}{8}$ in. diameter bars in two groups, making 18 bars in all. The steel represents 4·25 per cent. by volume of the bulk space occupied by the coarse aggregate and that material will have to be reduced by this amount.

The mix, therefore, will have the following quantities: 112 lb. cement, 220 lb. sand, and 552 lb. stone. It should be noted that this variation from the original mix design quantities is required only when the reinforcement is grouped so as to preclude the free assembly of the coarse aggregates in the reinforced zone; it does not apply to single layers of bars, since the effect then is as if part of the concrete had been boxed out or displaced by part of the formwork.

Where vibration is employed, advantage should be taken of the appreciable reduction produced in the viscosity of the concrete, enabling it to flow into restricted areas which it would fail to fill if any other method of placing were used. Close grouping allows an appreciable reduction in the overall width of a beam, with a consequent and worthwhile reduction in the dead load of the members. The grouping must be done in such a manner as to permit of the entry of the vibrtaor into the reinforced zone so that the concrete can be well compacted, thus ensuring a sound bond with the reinforcement. The space provided for the vibrator also serves as a filling space at points where the member is reinforced in its upper parts. In normal reinforcing practice, where top reinforcement is required the concrete has to be infiltrated through the bars. This has the disadvantage of limiting the maximum size of aggregate quite unnecessarily, while preventing the use of an internal vibrator of adequate size.

The introduction of vibration as a means of placing is beginning to have a profound effect upon almost every aspect of concreting. In the past, the degree of compaction likely to be attained on any job could never be assumed to be constant, nor could a definite value be set upon it in terms of mass per cubic foot; hence, since the percentage of voids present in any concrete has a most important bearing upon its strength and other qualities, no great reliance could be placed upon the finished product, resulting in the use of an undesirably large factor of safety. The correct and adequate use of vibration has greatly reduced the variations in packing that can arise in concrete as placed and thus it has become possible to design a mix so as to possess certain characteristics, both during placing and after curing. The success of a concrete designed for and placed by vibration depends upon two requirements common to all concretes, namely, the provision of raw materials of uniform characteristics and quality, and the combination of these materials in the correct proportion to form a homogeneous mix. Primarily, these conditions can be fulfilled only if suitable plant is available and operated with considerable technical skill. Unfortunately, as regards aggregates many plants are overworked and under-maintained so that, in spite of the wide tolerance permitted by B.S. 882, grading control is almost impossible. Furthermore, many suppliers do not appreciate the importance to the concrete engineer of maintaining their materials at constant values of grading and bulk density. It should be noted that constant grading in itself is not enough to cover an aggregate specification, as a change in particle shape will entirely alter the filler required at a particular water : cement ratio and aggregate : cement ratio. In the same way, the bulk density alone cannot fix the particle sizes and therefore the admittance size of the filler or fine aggregate will be indeterminate.

As the mechanisation of concreting increases, the demand for more precisely controlled raw materials will increase also. It may not be realised that a closely controlled aggregate is worth more money to the contractor, working to a modern specification, than an ill-controlled material, because the difference between the minimum required strength and the average strength can be reduced appreciably where a closely controlled aggregate is used. Thus, if the minimum strength requirement at 28 days is 3,000 lb. per square inch, the contractor using a variable grading may well have to aim at an average strength of 5,000 lb. per square inch employing a 6·5 : 1 aggregate : cement ratio to attain it, whereas, with a closely controlled gap-graded aggregate, the mean strength need not exceed 4,200 lb. per square inch; a reduction of 16 per cent., which can be attained with vibration placing and a 9·5 : 1 mix. The difference in cement content per cubic yard of these two concretes is 151 lb.

Cements, too, could be improved in regard to uniformity of performance. At present, cement drawn from a single works varies appreciably from batch to batch and this variation is accentuated when cement is delivered to a contract from two or more works. In these circumstances, variations have been put as high as 40 per cent. However, the reduction in cement variations can be achieved only if running costs are increased and further capital expenditure is undertaken and, until the variations due to poor grading control and indifferent mixing and placing are over-

come, such expenditure is not justified.

The combination of the concreting materials in the mixer, and the delivery from the mixer of these materials in a uniformly mingled state, is one of the major problems and anxieties of the concrete technologist. Some mixers give a better performance than others in regard to a particular type of mix, but most mixers produce a disconcerting degree of segregation when dealing with concretes which are suitable for vibration placing. Where the harsh mixes of low water content, that are particularly suited to vibration placing and the production of high-quality concrete, are concerned, many mixers have the unfortunate habit of retaining the fine aggregate within the mixer at the time of discharge, thus robbing the concrete of a large part of the filler. This loss of filler can be overcome to some extent by adding extra sand, as described earlier in the paper, but there is a danger of intermittent oversanding taking place when the fines in the drum of the mixer build up beyond the point where they can be retained. When this condition is reached much of the sand which has been held in the drum for two or three mixes is discharged at a single emptying, resulting in a marked change in the behaviour of the concrete under the influence of the vibrator.

One of the big advantages offered by vibration is the immediate stripping of formwork in either precast or cast *in situ* work. In the case of *in situ* work, which is perhaps the most important, lifts of up to 12 ft. can be placed and immediately stripped which allows the concrete surface to be treated in the green state by trowelling for fair face work, and by scoring where a render and set finish is required. Furthermore, the damage to shutters that are stripped from green concrete is far less than would occur with set concrete, particularly as the working faces of the forms require only hosing and brushing down to make them ready for the next lift.

It is hoped that a further advantage may arise from work that is proceeding at present; that is, elimination of tanking in basements and other structures designed to resist the ingress of water. It has always been possible to make effective water-retaining structures from concrete by the use of rather rich mixes and, in certain instances, the addition of one or other of the well known proprietary brands of sealing agents. However, the danger of the formation of shrinkage cracks, with a resulting seepage, was always present and where, as in the case of a basement, one of the concrete surfaces could not be examined and treated in the event of failure without a considerable amount of excavation, such a risk was not worth taking. The use of vibration in compacting carefully designed mixes, proportioned in such a way as to reduce overall shrinkage to a minimum while at the same time developing a high density, has made it possible to do without asphalt tanking in certain instances, and thus greatly reduce construction cost. As a rule, the mixes employed in this work are leaner than those generally found in reinforced concrete, which in itself reduces the cost of materials. The major saving, however, is due to the reduced excavation costs and the elimination of the asphalt and its protective covering. When vibration is correctly applied it is possible to reduce the frequency of construction joints, not only in road slabs but in other structural works. Where these joints are necessary the cost of their preparation for connection to new work can be reduced appreciably because, with correct mix design, no hacking is required; the only preliminary necessary to the addition of new concrete is hosing down to remove any deleterious matter covering the surface of the hardened concrete.

The development of prestressed concrete has focused the attention of structural engineers upon high-strength concrete and at the same time brought to notice two characteristics possessed by most concretes, but which have not been included in design calculations in the past. Both shrinkage and creep are of great importance in prestressed design and account for an increased high-tensile steel consumption of from 10 to 15 per cent. It is generally accepted that these two phenomena are associated with the cement paste, that is, with the quantity of water and cement contained in the mix. Recent developments have shown that, by careful mix design and the compaction of the concrete by vibration, strengths normally obtained with aggregate : cement ratios of 5 : 1 by weight can be attained with concrete as lean at 7 : 1. These not only contain less cement but less water, and consequently may be expected to develop lower values of shrinkage and creep. It is believed that a gap-graded concrete, having the same proportions as one continuously graded, will shrink and creep less than the continuously graded concrete because, in the former, the coarse aggregates are brought into intimate contact, thus forming a rigid skeleton which cannot shorten with loss of moisture and in which the creep is confined to a large extent to the plastic deformation associated with the rock from which the coarse material is derived.

In conclusion, the author would like to stress the very great need that exists today for qualified concrete technologists and certain classes of skilled operatives if the fullest advantage is to be taken of a very valuable engineering material. There is also, as always, the urgent need of laboratory and field research and development, both in regard to concrete itself and to the plant connected with its production.

King George VI Memorial Fund

The spontaneous demonstration of feeling which the nation experienced on the death of George VI has given rise to a wish to perpetuate his late Majesty's memory with a lasting expression of gratitude. The Lord Mayor of London has now opened a National Memorial Fund to give effect to this objective and readers are reminded that contributions to the Fund may be sent to The Lord Mayor at The Mansion House, London, E.C.4.

A.C. Portable Welding Set. Publication 133 received from The Quasi Arc Co. Ltd. gives a specification and information on the installation, operation and maintenance of the company's Type ACP 300 a.c. portable welding set.

High Voltage A.C. and D.C. Power Transmission.— In an article under this title in our March issue 1952, page 104, it is mentioned that the Gotland transmission scheme is scheduled for completion in 1953. The correct year is, however, 1954, the contract which was drawn up in 1950 definitely stipulating the later date.

The Pykara and Moyar Power Development

By R. DORAI RAJAN

This scheme, which has attracted considerable attention in India and other countries and which has been responsible for industrialisation of several districts of the Madras State, is now rapidly approaching completion. The Pykara site, on the northern slopes of the Nilgiris, a country similar to the Scottish Glens, offers great scope for the development of water power.

THE Pykara River, the largest of the streams draining the Nilgiris, rises about 15 miles west of Ootacamund, the well known hill station in India, at a height of about 7,000 ft. above sea level and falls in cascades from the Nilgiri slopes to the Mysore plateau, about 3,000 ft. above sea level. A head of about 3,100 ft., which is believed to be the highest in Asia and the fourth highest in the world, is available for power development. The upper reaches of the Pykara are called the Mukurti River from the fact that it rises from the Mukurti peak, which is 8,300 ft. above sea level and holds the record for the heaviest rainfall in South India. For six consecutive years, the Mukurti area experienced an average of 300 in. of rain, and in 1933-34, an abnormal rainfall of 442 in. was recorded —almost equal to Cherapunji in Assam, the wettest place in the world. During summer, the flow of Pykara is very low —3 to 4 cusecs—while during the monsoon, floods as high as 20,000 cusecs are quite usual. Such large fluctuations necessitate the provision of large storage reservoirs for controlling and regulating the flow. Taking advantage of the possibilities of the site, the engineers of the Madras Government have been constructing reservoirs gradually in accordance with the demands for power.

The first stage of development, completed in 1933, consisted of the installation of three 7,810 kVA units. For this purpose, a diversion weir across the Pykara River, a mile and a half above the Pykara Falls, was constructed and the water conveyed by a 7,000 ft. long aqueduct to the Glen Morgan forebay, this being situated on the edge of the plateau and having a capacity of 58 million cu. ft. This forebay is formed by two bunds, the lower being 63 ft. high with a core-wall 422 ft. long and supported by an earthen embankment 345 ft. broad at the bottom and 15 ft. at the top; the upper bund is 400 ft. long, 40 ft. high and 210 ft. wide at the bottom. The forebay intake is supplemented by another independent supply from the Glen Morgan reservoir, higher upstream and having a 45 ft. high dam with an effective capacity of 26 million cu. ft.

From the forebay the water is led through a valve tower having a motor-operated sluice to a riveted steel pipeline 1,035 ft. long and 78 in. diameter, ending with a simple surge tank having an overall height of

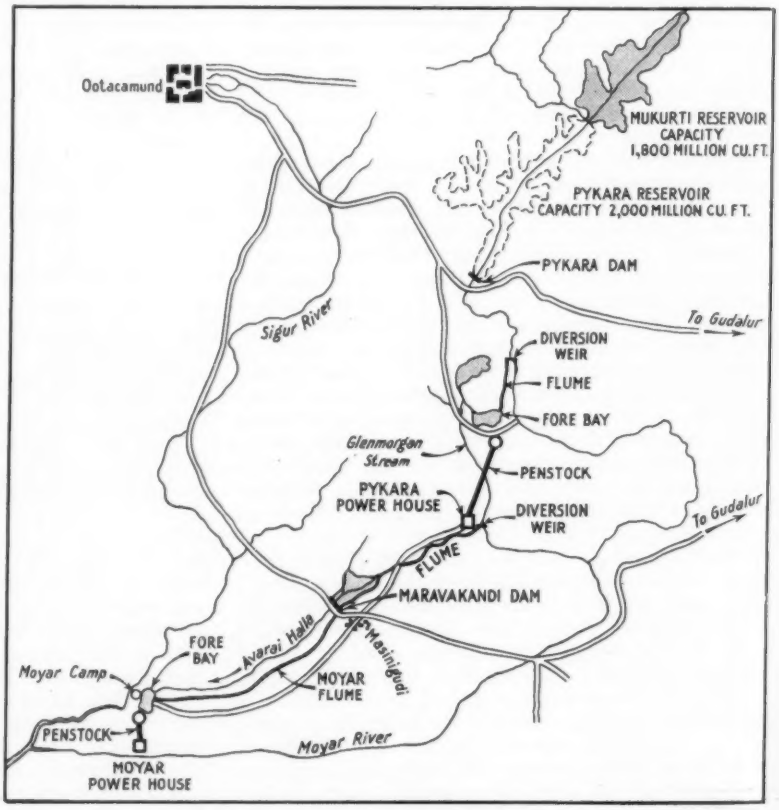


Fig. 1. Sketch map showing main features of Pykara and Moyar scheme

Fig. 2. Mukurti dam, impounding 1,800 million cu. ft. Shutters are to be installed during the second stage to increase the storage

Fig. 3. Penstocks, first stage of Pykara development

68 ft. and a diameter of 6 ft. 6 in., and a valve house. Venturi meters are provided for measuring the flow through the two penstocks. Each penstock is 9,268 ft. long from the surge tank to the power house and is 27 in. diameter on the top, tapering down to 21 in. near the power house at the point where the two pipes divide into three 16½ in. diameter branches, each of which serves one generating unit. Glenfield and Kennedy Limited supplied the control valves; the operating pressure in the valve chambers is 1,350 lb. per sq. in. but they were tested to over 2,000 lb. per sq. in. A haulage track along the penstock is also provided to carry men and material to and fro and to facilitate inspection of the penstock. These penstocks were manufactured and erected by Schweissrohr Verband of Dusseldorf, Germany, and were tested to 510 lb. per square inch in the upper section, 1,150 lb. midway and 1,710 lb. at the bottom.

Three impulse turbines of 10,900 h.p. supplied by

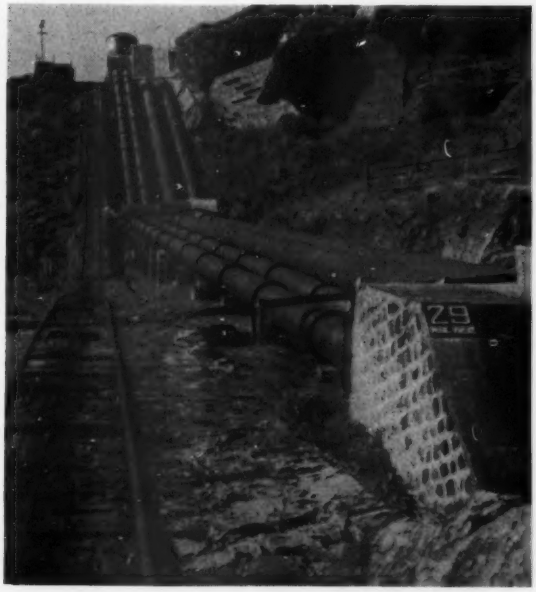


Fig. 4. Penstocks for all three stages, with surge tower in background

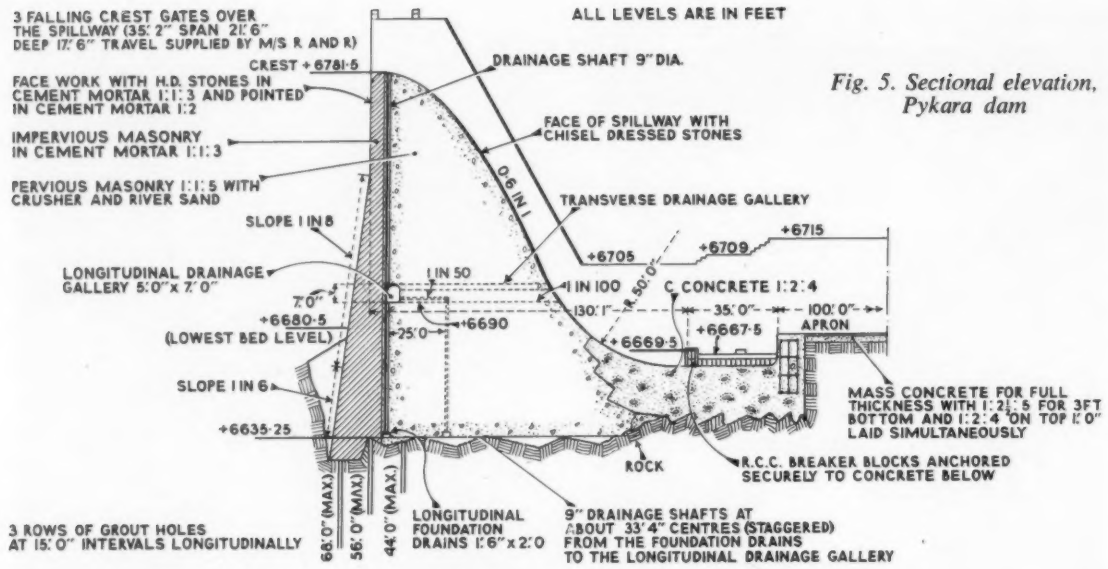

3 FALLING CREST GATES OVER THE SPILLWAY (35' 2" SPAN 21' 6" DEEP 17' 6" TRAVEL SUPPLIED BY M/S R AND R)
ALL LEVELS ARE IN FEET
CREST +6781·5
DRAINAGE SHAFT 9" DIA.
FACE WORK WITH H.D. STONES IN CEMENT MORTAR 1:1:3 AND POINTED IN CEMENT MORTAR 1:2
FACE OF SPILLWAY WITH CHISEL DRESSED STONES
IMPERVIOUS MASONRY IN CEMENT MORTAR 1:1:3
0·6 IN 1
PERVIOUS MASONRY 1:1:5 WITH CRUSHER AND RIVER SAND
TRANSVERSE DRAINAGE GALLERY
SLOPE 1 IN 8
+6715
+6709
+6705
LONGITUDINAL DRAINAGE GALLERY 5'0"x 7'0"
1 IN 50
1 IN 100
50'0"
C. CONCRETE 1:2:4
7'0"
130'1"
35'0"
100'0"
+6680·5
(LOWEST BED LEVEL)
25'0
+6690
+6667·5
APRON
+6669·5
SLOPE 1 IN 6
MASS CONCRETE FOR FULL THICKNESS WITH 1:2½:5 FOR 3FT BOTTOM AND 1:2:4 ON TOP 1'0" LAID SIMULTANEOUSLY
+6635·25
ROCK
R.C.C. BREAKER BLOCKS ANCHORED SECURELY TO CONCRETE BELOW
3 ROWS OF GROUT HOLES AT 15'0" INTERVALS LONGITUDINALLY
68'0" (MAX)
56'0" (MAX)
44'0" (MAX)
LONGITUDINAL FOUNDATION DRAINS 1'6"x 2'0
9" DRAINAGE SHAFTS AT ABOUT 33'4" CENTRES (STAGGERED) FROM THE FOUNDATION DRAINS TO THE LONGITUDINAL DRAINAGE GALLERY

Fig. 5. Sectional elevation, Pykara dam

Escher Wyss Limited, of Switzerland, are installed, operating under a gross static head of 3,080 ft. and running at 600 r.p.m. They are coupled to 7,810 kVA three-phase, 50 cycles, 11,000 volt alternators provided by Metropolitan-Vickers Electrical Co. Ltd., who also supplied the outdoor transformers. The switchgear was supplied by the British Thomson-Houston Co. Ltd. Generated at 11 kV the current was initially stepped up to 66 kV, but during the second stage to 110 kV and transmitted to Coimbatore on a double-circuit transmission line carried on galvanised steel towers, the normal span being 1,050 ft. and the longest 2,670 ft. A double-circuit telephone line on separate poles runs the whole length of the main transmission lines. From Coimbatore, power is transmitted over 66 kV lines to Erode in the east and Madura in the south, so linking the Pykara system with the Mettur and Papanasam systems to form a grid serving practically the entire southern portion of Madras State.

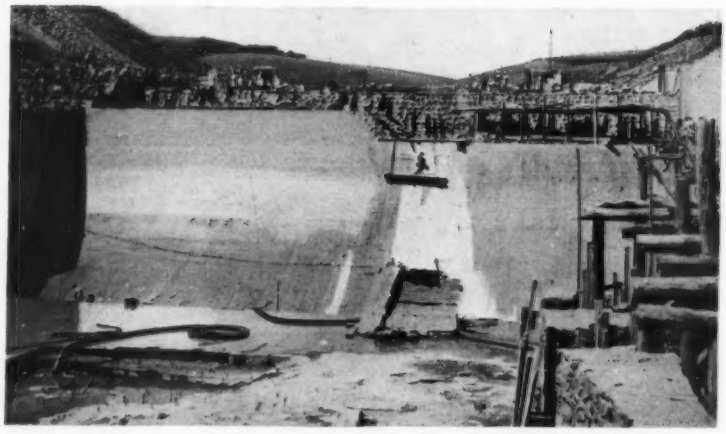


Fig. 6. Pykara dam under construction

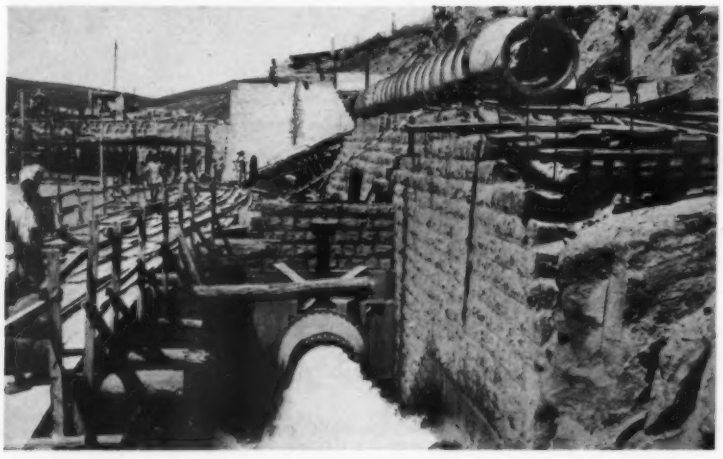


Fig. 7. Outlet pipes, Pykara dam

Owing to the increasing demand for power, a storage reservoir was constructed at Mukurti with a capacity of 1,800 million cu. ft. and during 1939 two generating units were added at the power house to develop a further 25,000 kW. The Mukurti Dam is an arch-type masonry structure constructed of random rubble in

Fig. 8. Penstocks on steepest part of hill

cement masonry with coursed rubble facing, and corewalls at the ends. During the monsoon period the overflow is about 10 ft. deep. The length of the dam is 600 ft., including the corewalls at the ends, the visible length being 530 ft. with a spillway 110 ft. long in the centre. The height from the lowest riverbed level to the spill level is 76 ft. Two 24 in. diameter outlet pipes with sluice gates upstream and needle valves downstream are inserted in the dam to release water at the rate of 180 cusecs for 100 days into the river, whence it flows to the Glen Morgan forebay. Shutters are provided over the spillway to enable the storage capacity to be raised from 1,600 million cu. ft. to 1,800 million cu. ft. before the dry season begins. The dam was constructed in stages, in step with the increasing demand for power.

A separate penstock is provided, 42 in. diameter at the top and 37½ in. at the bottom. At the power

Fig. 9. Pipeline and haulage track

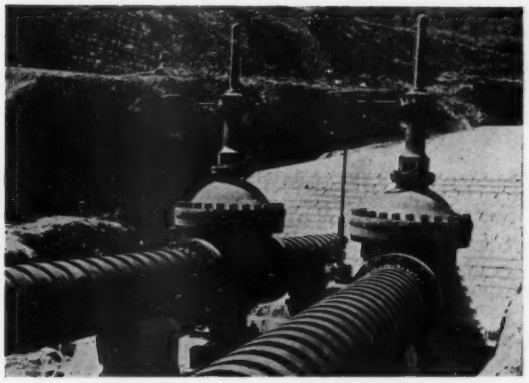


Fig. 11. Control valves for Pykara turbines

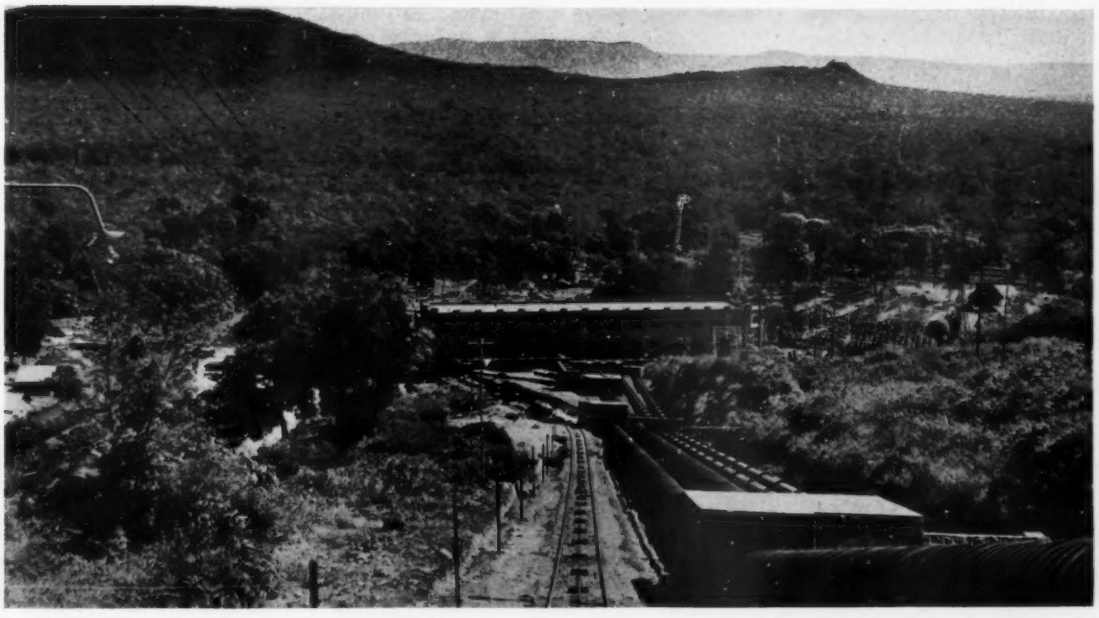


Fig. 10. Pykara powerhouse with a section of the pipeline

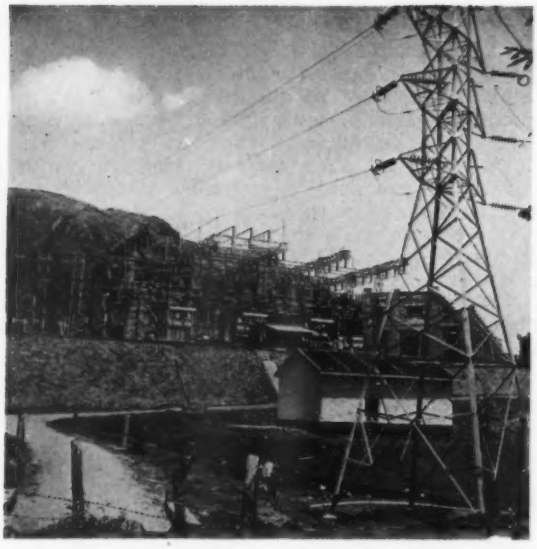


Fig. 12. Switching station, Pykara

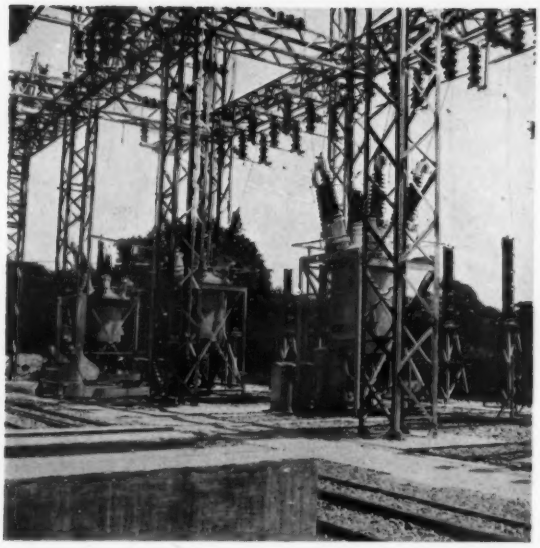


Fig. 13. Transformers, Pykara

house, the penstock trifurcates into two distribution pipes of 23 in. diameter and one of 16½ in. diameter, the larger feeding the two new 18,750 h.p. turbines and the third the existing 10,000 h.p. turbine of the first stage. The new turbines were also of Escher Wyss manufacture. The distribution pipes are of hard-drawn seamless steel with a tensile strength of 32 tons per sq. in.

Each of the two new generating units comprises an 18,750 h.p. single-jet, single-runner impulse wheel having a speed of 600 r.p.m. coupled to a 12,500 kW, 3-phase, 50 cycle generator. These two units operate, of course, in conjunction with the three previous sets. The generators and the outdoor transformers were supplied by the Metropolitan-Vickers Electrical Co. Ltd.

As the station capacity is once again fully exhausted further storage has been necessitated. The third stage, which is to cost, including transmission lines, over Rs. 4 crores, is now in progress. It consists of the construction of a dam to store 2,000 million cu. ft. of water on the Pykara River, just above the bridge on the Ootacamund-Mysore road. Two units of 13,600 kW each will be installed in the existing power house.

The Pykara dam, work on which is in progress, will control a catchment of 38 sq. miles with an average rainfall of 80 to 100 in. and an annual run-off of 7,000 million cu. ft. With a reservoir storage of 2,000 million cu. ft., 200 cusecs can be drawn for 100 days. The superficial area of the reservoir, the largest so far provided on the Nilgiris, will be 1,000 acres. The length of the dam will be 635 ft., and

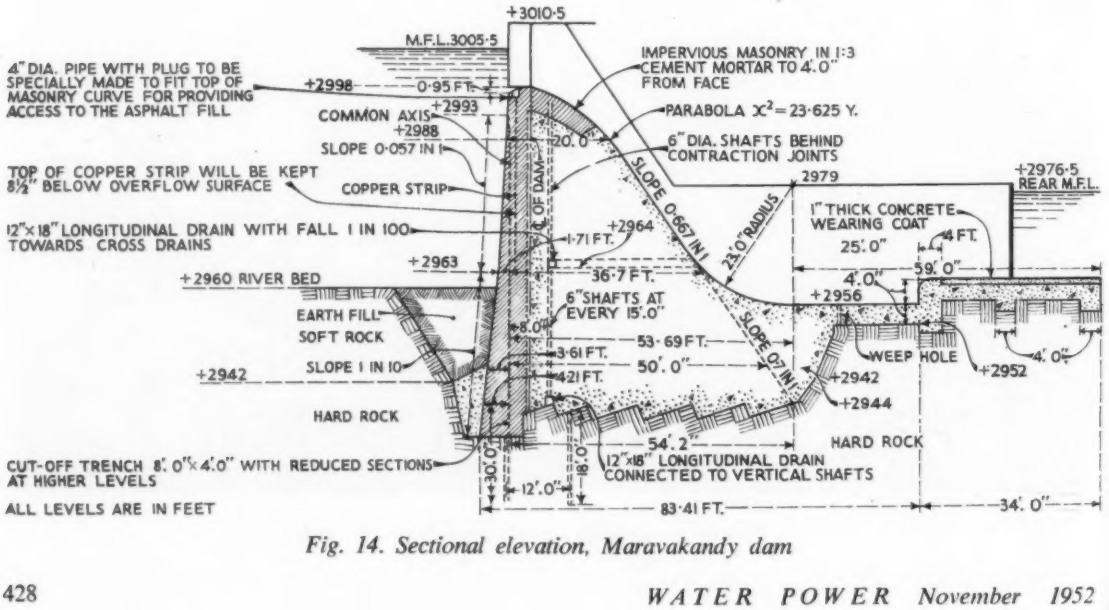


Fig. 14. Sectional elevation, Maravakandy dam

height 173 ft. above the deepest foundation and 120 ft. above mean river-bed level. The spillway, which is in the centre is 121·5 ft. long, will have three lift gates 35 ft. wide and 18 ft. high, capable of passing a maximum flood of 31,000 cusecs. The dam is divided into two parts; on the left flank, where rocky foundations are available, a length of 445 ft. is being built of rough stone in cement masonry, and while the right flank, to a length of 170 ft. is being constructed as an earth dam with a concrete corewall taken deep into the side of the hill where the foundations are unstable. This corewall is about 170 ft. high, the lowermost 50 ft. being 10 ft. wide and the rest having a batter of 1 in 3·5 on both sides, thus reducing the top width to 3 ft. The corewall is enclosed in an earth bund, the upstream side of which is protected by a three-feet thick revetment. To protect the rear slope from erosion it has been covered with turf. Two pipes, 6 ft. diameter and 184 ft. long, and each capable of discharging 200 cusecs, are built up in the left flank. These are constructed of ½ in. steel plates and will ultimately be coupled with 2,000 kW hydro sets.

The water conserved by the dam will be discharged under control into the river and thence through the diversion weir to the Glen Morgan forebay. Here the existing surge tank has been converted into a differential type to serve the third stage of the scheme. To serve this end the 15 ft. diameter outer shell of the tank, as now converted, is provided with five port holes leading to the inner shell. A fourth penstock takes off from an existing blank flange (inserted in the second stage) and is 42 in. diameter at the top, tapering down successively to 39 in., 37½ in. and 26 in. at the bottom; it is held in position by 31 concrete anchors. The entire penstock was supplied by Ferrum (England) Limited and consists of 20 ft. sections weighing on average five tons, the maximum weight of certain sections being, however, nine tons. They are tested for a working pressure of 1,700 lb. per sq. in. and each is provided with an expansion joint in view of the high temperature variations experienced in this locality. This penstock is designed to discharge a maximum of 140 cusecs. In the first stage the discharge was limited to 45 cusecs in each of the two pipes initially provided and as the two pipes under the second and third stages will each have a capacity of 140 cusecs, the total discharge of all the four pipes will be 370 cu. ft. per sec.

Each set comprises an impulse turbine direct coupled to a generator, the whole being arranged horizontally. The turbines are of the single-wheel single-jet type running at 600 r.p.m. and have a capacity of 20,000 h.p. They were manufactured by Escher Wyss Limited of Switzerland, the generators being of Metropolitan-Vickers manufacture and designed for an output of 13,600 kW each at 0·85 p.f., 11,000 volts a.c., 3-phase, 50 cycles. The indoor switchgear was also supplied by Metropolitan-Vickers Electrical Co. Ltd., while the outdoor transformer and switchgear were supplied by the English Electric Co. Ltd.

The power station at Singara is being extended 128 ft. to the westward to accommodate the two new units, so that its present length of 212 ft. will ultimately become 340 ft.; the width is 54 ft. The transformer yard is also being proportionately extended.

The scheme is expected to be completed and commissioned at the end of 1953.

The First Hundred Years

There is a fine challenge in the title that Glenfield & Kennedy Limited have chosen for the historical survey they have published by way of celebrating the centenary of their activities, for a "first" hundred presupposes succeeding hundreds and although our interest in the third and fourth hundreds may be rather attenuated, we have every conviction the firm will even then still be a very live concern and doing excellent work. But perhaps this is carrying prognostication a little far, for if we are to judge by the illustrations of equipment manufactured in 1852, we have to acknowledge that the mind is quite unable to envisage the kinds and types of equipment that will be in production in 2052; all we can say is that if they are made by Glenfield & Kennedy Limited they will be good.

Besides the publication we have mentioned the centenary was celebrated by a luncheon and visit to the extensive works at Kilmarnock, speeches being given by the chairman, Mr. H. Cowan-Douglas, C.A., Lord Bilsland, and by the Earl of Home. In the course of his remarks, Lord Bilsland reviewed the history of the firm, which was now, he stated, recognised throughout the world as playing a leading part in the design and construction of equipment for the control of liquids and served practically every industry, although the larger part of its production was necessarily concerned with hydro-electric development, water supply schemes, irrigation projects and the control of flood discharge from reservoirs and over river barrages. He also referred to a relatively new development—the hydraulic elevator fish pass—and concluded by saying that 40 per cent. of the current production was for export and that last year the company's products reached no fewer than 79 countries.

Developments of Hydro-Electric Power in Norway
(continued from page 419)

up to 10,000, 17,000 and 50,000 V. Owing to the low head and correspondingly slow speed these generating sets are comparatively large; thus the height of the turbine measured from the top of the draught tube is 6·25 m., the total length 13 m., and the weight 230 tons. The electric generator measures 8 m. in diameter and weighs 150 tons.

The Raanaasfoss station was built in 1918-1921 and has been running to everybody's satisfaction ever since. It is the property of the Norwegian county of Akershus. Apart from State plants and private companies, it is usual in Norway for the different counties to build stations to supply their inhabitants and local industries, but as the different counties are not always provided with water power in proportion to the number of inhabitants or to industrial needs, an extensive intercommunication network has been established. Practically the whole of south-eastern Norway is thus electrically interconnected.

The Glockner-Kaprun Generators

Prof. Dr. H. Sequenz, of Elin, Vienna, describes the special design features of the generators supplied to this important Austrian station

AS far back as 1926, Messrs. AEG of Berlin investigated the hydro-electric power potentialities of the Tauern territory, a mountain range of 2,000—3,000 m. (6,500—10,000 ft.) forming part of the Austrian Central Alps. In 1928, they submitted a draft project for harnessing the waters of the Tauern territory, comprising three storage reservoirs: Tauernmoos reservoir in the Stubach Valley, Mooserboden reservoir in the Kaprun Valley and the reservoir at Wasserfassboden, to be fed through a system of surface channels along the slopes, about 1,200 km. (750 miles) long, at an altitude of 2,200 m. (7,200 ft.).

In December 1928 another project was put forward, providing four main sections: Venediger power plant, Glockner power plant, the Isel river, Moell Creek, and Lake Weissensee, and a group of run-of-river plants along the Draw.

Finally, Messrs. Alpenelektrowerke - Aktiengesellschaft, established in 1938, elaborated a scheme to utilise the water power in two steps: a main power house at Kaprun with the storage reservoir at Wasserfallboden, incorporating Limberg Dam, and an upper power house on Mooserboden. A balancing reservoir was proposed on Margaritzenboden.

Construction work was commenced in 1938, but its progress was hampered more and more by the war, and in 1945 the site was abandoned. In May 1946, construction work was recommenced, and in September 1951 the main power plant was completed by the completion of Limberg dam (Fig. 1). It is a winter storage plant, producing in a normal year 207 million kWh, i.e. 184 million kWh in winter and 23 million kWh in summer.

The Glockner - Kaprun group will finally comprise the main power plant, Kaprun, the upper power plant, Limberg, two reservoirs at Wasserfallboden and Mooserboden, a tunnel for the water of the Moell Creek with a smaller reservoir at Margaritze, and several creek intakes.

The annual capacity of the Glockner-Kaprun power plants, without pumping service, amounts to 617 million kWh, i.e. 455 million kWh from October to March and 162 million kWh from April to September.

The New Generators

The total generating capacity installed in the main power house at Kaprun amounts to 200 MW. Two sets of 50 MVA each were put into commercial operation in 1944 and 1945. A third set of 70 MVA has been in operation since September 1951, and a fourth 70 MVA set since the beginning of this year.

The turbines of both the first sets are single-nozzle twin impulse turbines with an output of 128,000 h.p. at 500 r.p.m. The turbine output for the new sets has been increased to 83,000 h.p. each. It was necessary to revert to a double-nozzle arrangement which permitted the width of the runner to be reduced.

All sets are arranged in the same manner, the rotor of the generator being supported by two bearings and the turbine runners overhung on either side. This two-

Fig. 1. The Limberg dam in August 1951

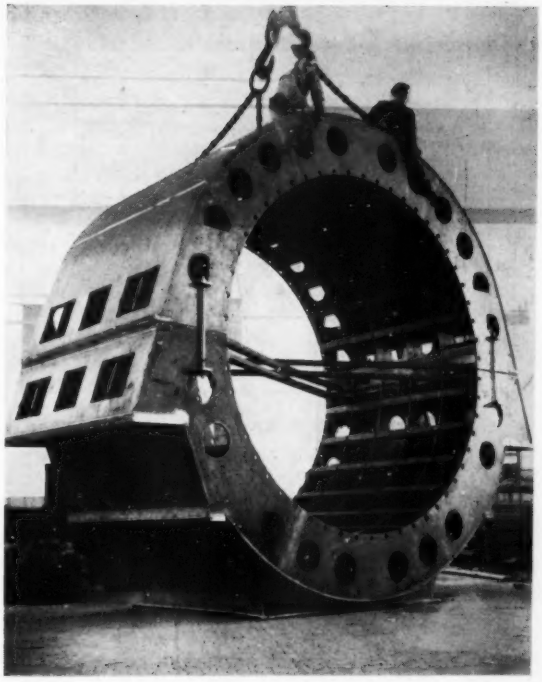


Fig. 2. The two halves of the stator frame assembled

bearing design permits simplified mounting and dismantling of the turbine runners, as well as operation of the set with only one turbine and half the generator capacity.

The New Generators as Limit-Capacity Machines

The new 70 MVA 500 r.p.m. generators must be considered as limit-capacity machines. Esson's equation for the capacity of synchronous machines reads:

$$N = CD^2 ln \qquad (1)$$

C stands for Esson's factor of utilisation which can be assumed to be $6 \frac{\text{kVA} \cdot \text{minute}}{\text{m}^3}$ for limit-capacity machines. D and l signify diameter and length of active armature iron in metres, whereas n denotes speed in r.p.m. N is the capacity in kVA.

The ratio of runaway speed to nominal speed being r, the maximum admissible circumferential velocity is obtained with

$$V_{max} = r \frac{D\pi n}{60} \text{ m/sec} \qquad (2)$$

The equations (1) and (2) can be transformed to give a formula for the limit capacity per metre length of armature iron:

$$\frac{N}{l} = C \frac{60^2}{\pi^2} \frac{V_{max}}{r^2} \frac{l}{n} 10^{-3} \text{ MVA/m} \qquad (3)$$

We consider now a speed of $V_{max} = 150$ m/sec as the limit of circumferential velocity. With a runaway speed of 933 r.p.m. and a nominal speed of $n = 500$ r.p.m., ratio $r = 1{,}866$. Introducing these figures in equation (3), it will result in $\frac{N}{l} = 28$ MVA/m.

Considering the maximum length of armature iron for limit-capacity machines as being $l = 2{\cdot}5$ m. (8 ft. $2\frac{1}{2}$ in.), the above formula will result in a limit capacity of $N = 70$ MVA, which is exactly the capacity of the new Kaprun generators.

Towards the end of the second world war, it was stated with some justifiable pride that horizontal-shaft generators for high-head plants had been built up to

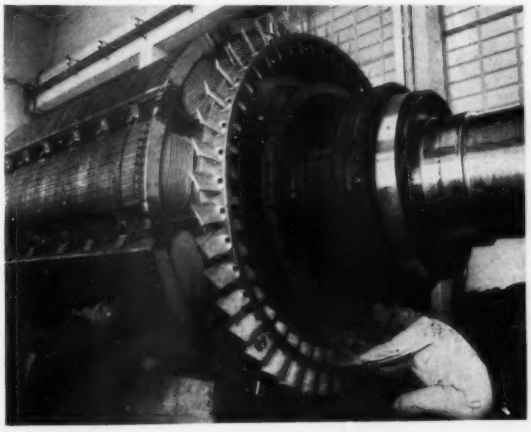


Fig. 4. Exciter side of rotor, showing fans

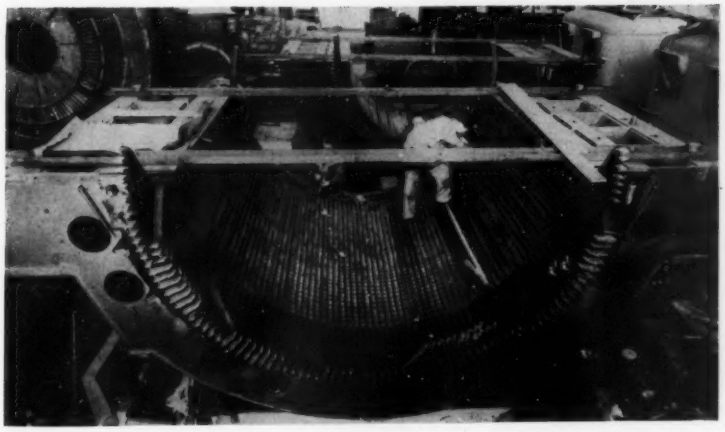


Fig. 3. Winding the lower half of the stator

55 MVA at 500 r.p.m. Having regard to the high runaway speed of water turbines, the manufacture of such high-speed generators was considered to be quite an extraordinary achievement. The Kaprun generator, with its capacity of 70 MVA, surpasses the above mentioned hydro-electric generator by 28 per cent.

Special Design Requirements

The generators are designed for 70 MVA at 500 r.p.m., 10,250 V, 3,950 A, and a power factor of 0·8. The runaway speed is 933 r.p.m. It was necessary to mount the generators on existing foundations which had been prepared for machines of only 60 MVA. This implied the installation of about 16 per cent. more capacity on the foundations.

Also the method of ventilation was modified. Both of the earlier generators are designed for straight-through ventilation, whereas the new ones were to have a closed-circuit ventilation with water cooling of the circulating air. In spite of this change from fresh-air ventilation to closed-circuit ventilation, modifications of the foundations had to be avoided as far as possible.

Main Dimensions

The inside diameter of the stator is 3·05 m. (10 ft.) and the total length of armature iron including cooling channels is 2·6 m. (8 ft. 6 in.). Yet it was possible to transport the completed stator with its winding in two halves on the railway, surpassing the standard loading gauge on both sides by 300 mm. (1 ft.). The shipping weights are 68 tons for the lower part of the stator, and 64 tons for the upper part.

The centrifugal forces at a runaway speed of 933 r.p.m. and a peripheral speed of 150 m. per sec. (490 ft. per sec.) could still be controlled by a simple comb-type rotor. For transporting the complete rotor, weighing with its poles 165 tons, a special low platform railway truck with 18 pairs of wheels was used. The total weight of the generator is 325 tons.

Stator and Stator Winding

The stator casing is horizontally split and is of welded steel construction. The laminations are arranged to allow for thermal expansion and the pitch of the cooling ducts is reduced towards the middle of the generator. As a consequence of this the temperatures, as measured by means of temperature detectors embedded between the two conductors of the slot, have been found to be practically equal in the middle and at both ends of the slots. These measurements were made during short-circuit test in the test shop.

With 162 slots and 12 poles, the stator has a fractional pitch winding of 4½ slots per pole and phase. It is a double-layer wave winding with two parallel branches per phase. To suppress higher harmonics, a short-pitch winding was selected. The conductors of the stator are composed of many individual conductors each insulated with glass silk, and stranded so that each of them is placed only for a short stretch at the inner face of the stator, thus providing favourable conditions with regard to the losses caused by the axial flux entering the open slots and the transverse component of the leakage flux.

For insulating the bars of the stator winding, asphalt micafolium has been used. Inside the slots there is a thin slide lining to prevent the corona protection of the bars from being damaged by the sharp edges at

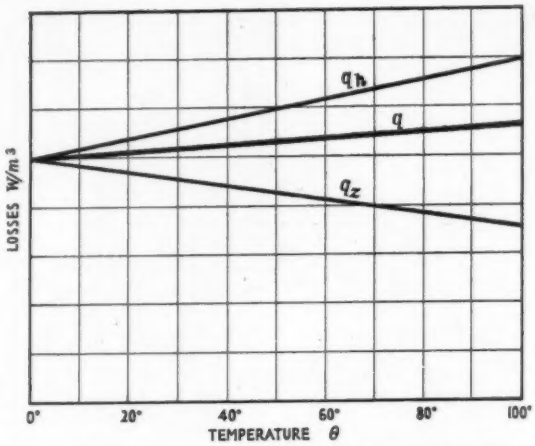


Fig. 5. Curves of losses within the practical range of temperature rise

the cooling ducts inside the stator iron. This slide lining is perforated and impregnated with conductive varnish to guarantee a reliable earthing of the corona protection. Only such bars were used which had practically no inclusions of air in them, and only a very small clearance was allowed between bar and slot. In this way, very good heat-dissipating properties were obtained so that in spite of the high utilisation the temperature rise of the winding under full load will not exceed 70°C.

Thirteen plates, forming the body of the rotor, are shrunken to the star-shaped shaft. The rotor blades are chromium-nickel-molybdenum steel, manufactured by Gebreuder Boehler. Cooling ducts are provided between some of the plates. Circumferential grooves are machined in the plates to engage with the combs of the poles.

The poles are composed of 2 mm. (0·08 in.) steel stampings, compressed by heavy end plates. Shorter and longer assemblies alternate in building up the poles, thus providing the comb-shaped profile which engages with the grooves on the rotor body with a lateral clearance of only 0·2 mm. (0·008 in.). The poles are fastened by axial bolts passing through the combs of the poles and through the rotor plates. The shape of the pole shoes is such that the air gap increases to double its width towards the edges of the poles.

The excitation coils are of edge-wound flat copper strip with inside dimensions of 2,700 mm. × 330 mm. (8 ft. 10 in. × 1 ft. 1 in.), and a weight of 850 kg. (870 lb.) each. The copper section is 70 × 4·5 mm.² (2·76 × 0·177 sq. in.). A heavy damper winding is fitted to the pole shoes.

As a pilot exciter was not practicable in this instance, a split-pole exciter has been adopted, situated between the generator and one of the bearings. The existing foundations imposed a limited distance between the bearings and as a consequence the exciter is of very compact design.

Bearings

The bearings are designed for a load of 96 tons each and oil is supplied by an electrically driven pump during starting and by a mechanically driven pump when running. Each bearing is equipped with a pressure oil pump for lifting up the rotor for starting,

stopping, and maintenance purposes. When oil pressure is applied and the shaft is floating on an oil film, the heavy rotor can be turned by hand.

Losses and Efficiency

By careful workmanship it was possible to keep down the iron losses at nominal voltage, including pole-face and end-plate losses, to the figure of 356 kW. This is the more remarkable as the laminations are made of sheet with a specific loss of 0·9 W per lb. at 50 cycles and 10,000 CGS lines.

In the temperature test on electric machines, it has been common practice to neglect the influence of temperature on the stray losses, because stray losses are affected in the opposite way to the main loss, thus causing certain mathematical difficulties. By introducing a resulting temperature coefficient, A. Hochrainer has demonstrated that the influence of temperature on stray losses can be accounted for in a simple way within the practical range of 80°C. The diagram in Fig. 5 shows main loss q_h, stray losses q_z, and total losses q plotted against temperature rise. For the purpose of this graph it is assumed that at a temperature of $\theta=0$, the main and stray losses are equal. As may be seen, the course of q is practically horizontal. Therefore it is possible to account for the temperature rise in the following equation:

$$q = q_o(1+a\theta) \qquad (4)$$

q_o stands for the quantity of heat in the unit of volume at ambient temperature, i.e. at $\theta=0$, a is a temperature coefficient that is obtained very simply by calculating the losses at two widely differing temperatures, for instance, at $\theta=0$ and $\theta=80$. If Q_o and Q signify the total losses within the portion of conductor under consideration, then

$$a = \frac{Q - Q_o}{Q_o\theta} \qquad (5)$$

Since the stray losses are different in different parts of the armature conductors — for instance in the portion enclosed in the slots the losses are considerably higher than at the ends — it is necessary to calculate an individual temperature coefficient for each part, and to use the coefficient when solving the differential equation of temperature rise.

The stray losses at nominal current are 170 kW or 2·4 per cent. of nominal rating. For the portion of the windings embedded in the slots, the temperature coefficient a obtained with the above method of calculation is 0·00138 per °C., and for the coil ends the figure is 0·0027 per °C.

The efficiencies, obtained by the method of separation of losses, are:—

Load	Unity power factor	0·8 power factor
%	%	%
100	98·34	97·83
75	98·08	97·53
50	97·47	96·78
25	95·42	94·29

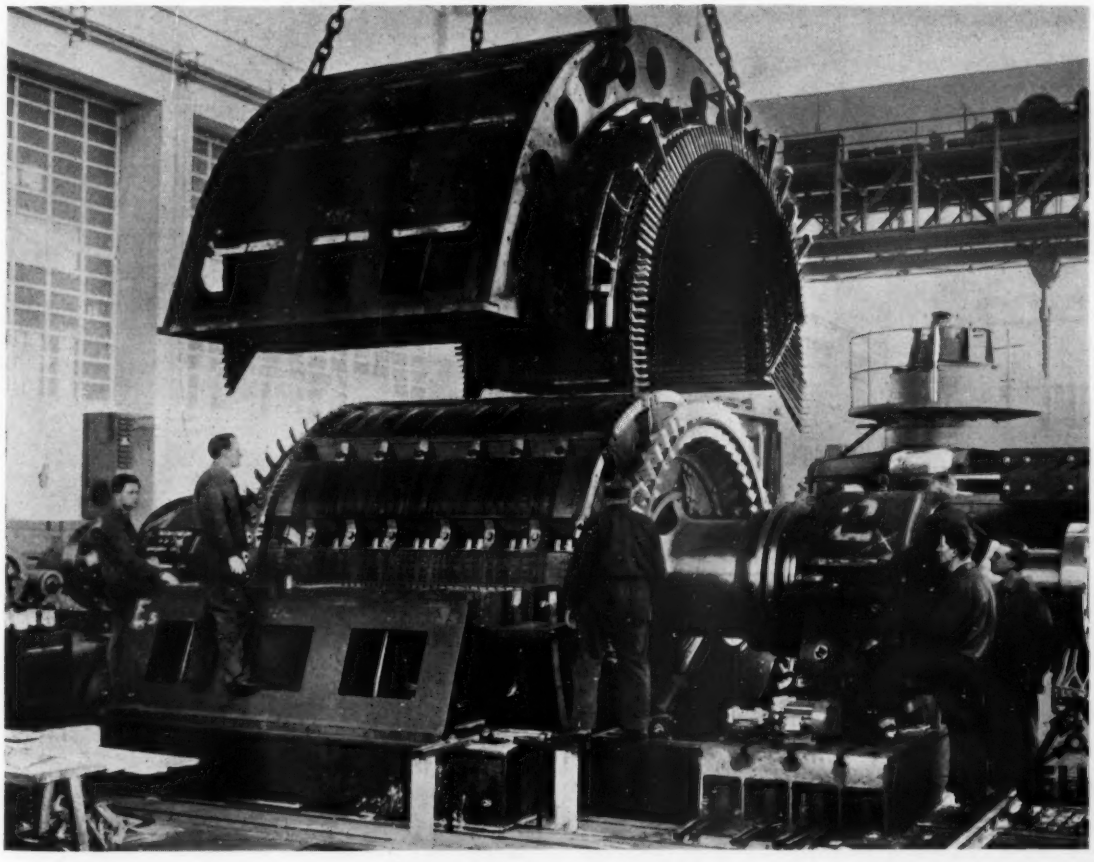


Fig. 6. Assembling the generator

The temperature measurements reveal that the generator, in spite of its high degree of utilisation, still has an ample overload capacity. The admissible limits of temperature rise would not be exceeded under a load of 80 MVA.

Ventilation

Ventilation investigations showed a certain superiority of the axial fan as compared with the centrifugal fan, as regards both the quantity delivered and its performance under throttling conditions.

The axial fan was designed according to the usual method though with an ample addition to the delivered pressure. With an angle of adjustment 5° greater than calculated, the expected quantity of delivered air was surpassed by 20 per cent.

On both sides of the rotor two fans are provided in the form of two rings of axial fan blades, arranged radially one outside the other (Fig. 6). The outer fan serves the coil ends of the stator and the gaps between the poles, and the inside fan serves the centre of the generator. The spacers in the cooling ducts are also designed like fan blades to increase the discharge capacity of the inner fan. To keep the intake losses of the fans at a low value, guide vanes are arranged in the end covers. The total quantity of ventilating air for each side of the generator is 25 to 30 cu. m. per sec. (875 to 1,050 cu. ft. per sec.).

A special design of the fan blades permits setting their adjustment angle according to the result of the test-shop measurements.

The shipping of the 70 MVA generator from the Weiz plant of Messrs. ELIN to Kaprun was one of the greatest transportation feats ever accomplished by the Austrian Federal Railways.

In September 1951, the completion of the Limberg dam was celebrated, and as part of this celebration the third generating set was placed in commission.

Tension-Type Sluice Gates

The accompanying photographic reproductions and drawings illustrate an interesting type of sluice gate which was designed by Mr. W. J. Bowtell and is now being manufactured by Head, Wrightson & Co. Ltd., of Thornaby-on-Tees. Its primary merit is that it enables the metal forming the gate to be used entirely in tension, thus utilising to the full its strongest quality, so enabling a substantial reduction to be made in the weight required for any particular duty. The actual gate takes the form of a segment having its concave surface facing upstream, the water load being transmitted to grooves in the pier supports either by trains of rollers or, in the case of small gates, by wheels. Beams are fitted at either end of the segment to give vertical support and rigidity so that when the gate is in use the metal plate is wholly in tension and tends to retain its correct form in virtue of the pressure of the retained water.

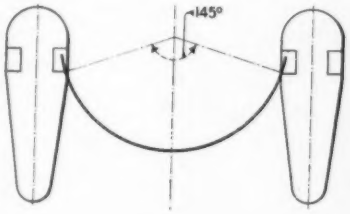


Fig. 1. Diagram showing general arrangement of tension - type gate

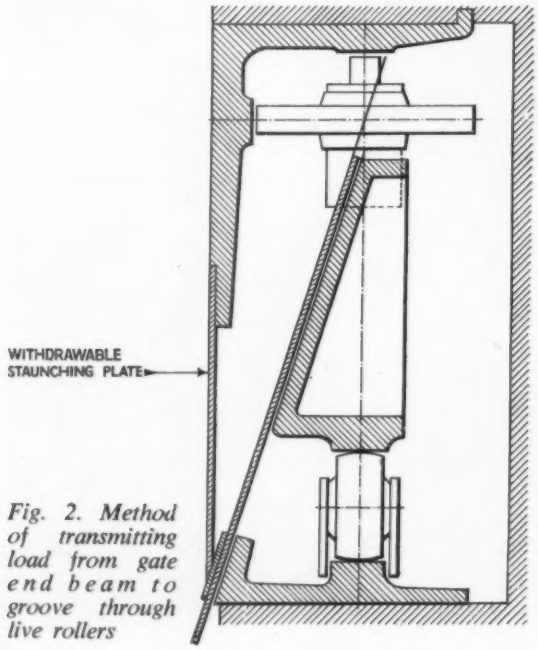


Fig. 2. Method of transmitting load from gate end beam to groove through live rollers

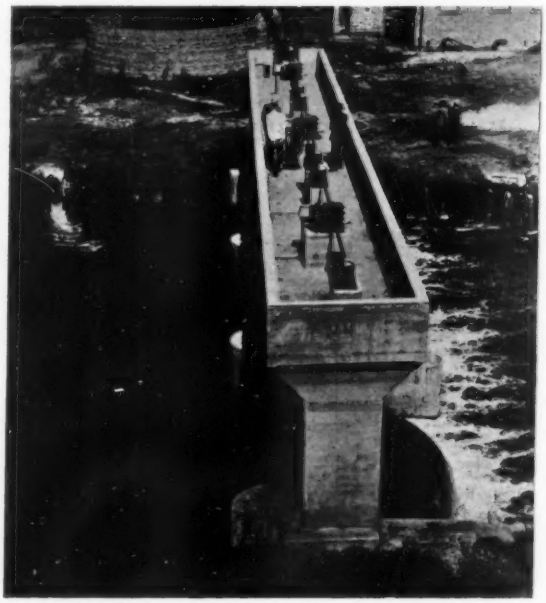


Fig. 3. Sluice gate in lowered position

Compared with a gate of a similar width of opening and depth, this gate has a larger surface area, but because it does not have to be reinforced against bending stresses, a considerable saving in metal can be attained. When steel is used, the large sizes of gates are little more than half the weight of com-

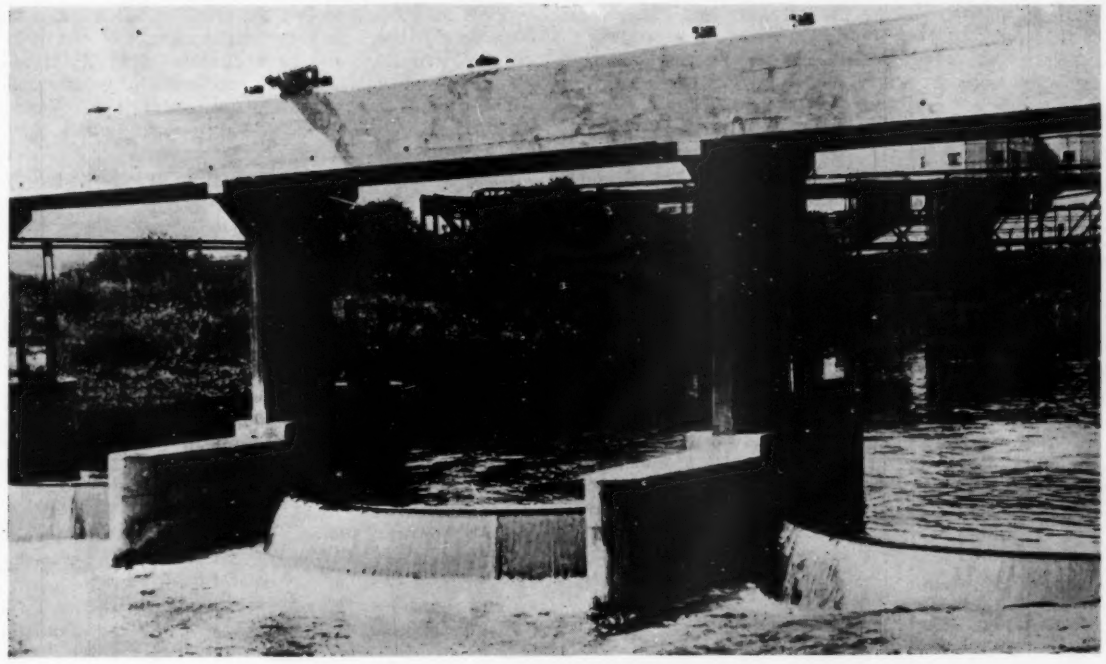


Fig. 4. Further view of gates in lowered position

parable gates of normal design. Further weight reduction is made possible by the use of aluminium alloy, a material which is particularly suitable for this type; this in turn leads to less need for counterbalancing.

Very little stiffening is required beyond an angle or flat bar along the top and bottom edges, while joints on the plates need only flat bar covers. In the case of the larger gates, an occasional vertical stiffening angle may be attached. There are therefore no girders on which silt and organic matter can accumulate—an important consideration in certain conditions. Further, the generally clean design makes all parts easily accessible for cleaning and painting.

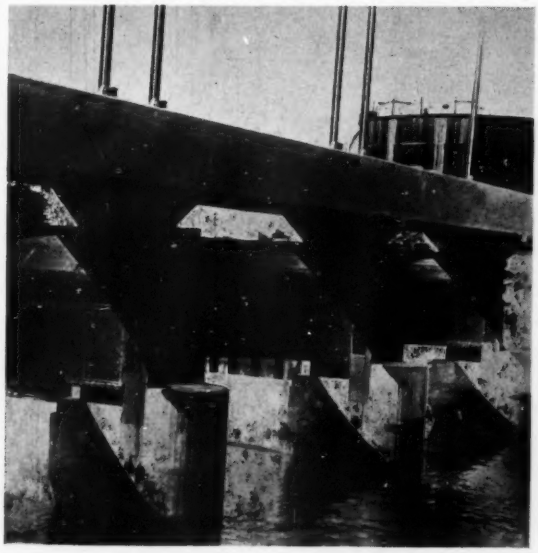


Fig. 5. Gates in fully raised position

The bottom of the gate closes on to a curved metal sill built into the floor of the sluiceway, and should a high degree of watertightness be required, a rubber strip is fitted to bear upon the sill. Because of the curved shape, a simple greenheart sill cannot be used.

Originally, the design incorporated full semi-cylindrical gates, and three of this type have already been installed in Britain; but in the latest model, the gate subtends an angle of only 145°, resulting in a saving of material, and allowing simpler pier design and construction. Six gates of this latest type are at present being built for a scheme in Trinidad. They are constructed of $\frac{5}{16}$ in. aluminium alloy plate, have a 25 ft. width of opening, are 7 ft. in depth and have a 9 ft. lift.

Fig. shows the sealing arrangements; at the point where the gate enters the groove, the end beam is connected to the tangential extension of the plates, the water load on the gate then being transmitted through live rollers to the groove. As the rollers are offset to the gate, a turning moment is produced which is balanced by auxiliary wheels carried by the end beam and bearing on a steel member connected to the upstream face of the groove. The load on these wheels is about 30 per cent. of that on the rollers.

The load from the auxiliary wheels causes a bending moment on the groove member, but this is largely, or even completely, balanced by the pressure of the water on the outside face.

A feature of the design is the almost complete elimination of eddies causing roller vibration when the gate is partly open. This is achieved by largely enclosing the groove by a staunching plate attached to the upstream groove member, resulting in a very

narrow opening facing downstream (see Fig. 2).

Certain detail variations are available according to the size and purpose of the gate. For instance, wheels may be used in place of the live rollers in certain cases where pressures are not high. In very small gates, the auxiliary wheels may be omitted, the end beam being modified to bear frictionally on to the upstream groove member. The staunching plate may be fitted with a flexible end strip for heavy loads.

There are, of course, limitations to the use of this type of gate, as it is not designed to withstand any considerable load in the reverse direction, but it is eminently suitable for open channels such as rivers and canals. The gate can be reinforced to meet small reverse loads, and in the case of the Trinidad gates, rolled joists have been added to take small tidal reverse pressures.

Operation of the gates can be by rope and pulley or by rack and pinion, and provision can be made for manual or electrical operation.

Abstracts from the World Technical Press

The Aussois Scheme, France

The Aussois hydro-electric installation is a typical example of many installations in the French Alps, with a power plant running under a very high head, and intakes sited at uncommonly high altitudes; the intake works and their tunnels extend over a length of about 12.5 miles at 6,560 ft. The main advantages of such plants are, on the one hand, the high head itself, which, even at a restricted discharge, ensures high power capacities, and on the other, the glacial regime of the streams which depends much less on the irregularity of precipitation than a regime determined by rainfall or snowfall.

The Doron de Termignon, which flows into the Arc 10.5 miles upstream of Modane, drains glacial waters from the Vanoise massif; after an initial major intake (two-thirds of the catchment area) at the confluence of the Leisse and Rocheure, the supply tunnel collects the water from all right-bank tributaries of the Doron as well as from the right-bank tributaries of the Arc between Termignon and Avrieux.

The importance of this project, considered at the outset solely from the aspect of hydro-electric power generation, greatly increased after the war when it was decided to use part of the water power available to drive a modern blowing plant to serve a testing installation for sonic and supersonic speeds.

The main characteristics of the Aussois scheme are:

Catchment area	62.9 sq. miles.
Installed capacity	90,000 kVA,
Maximum gross head	2,805 ft.
Discharge	423.79 cusecs.
Aggregate production	325 M kWh, of which 60 M kWh are consumed by the blowing plant

The principal works are:—

(a) the main Doron intake at 6,585 ft., diverting 423.79 cusecs. from a catchment area of 39.75 sq. miles at the Entre-deux-Eaux site, and secondary intakes on the Doron and Arc tributaries;

(b) a supply tunnel 18,131 yards in length at 6,560 ft. with a gradient of 2 mm. per metre, and a cross section of 86.11 to 107.63 sq. ft.;

(c) seven intermediate intakes collecting the waters of the catchment areas;

(d) a dam, forming an intake on the Avrieux torrent (catchment area 9.26 sq. miles), with a reservoir of 141 M cu. ft. called Plan d'Aval; the maximum storage level is fixed at 6,389 ft.

(e) a supply pressure tunnel about 2,308 yards in

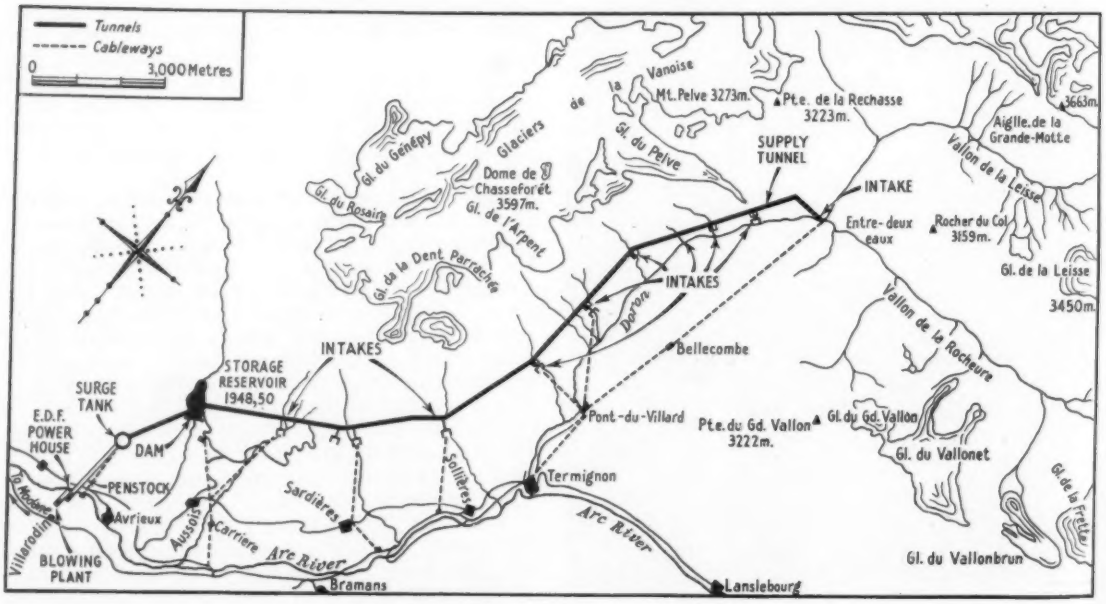


Fig. 1. Location of the Aussois scheme

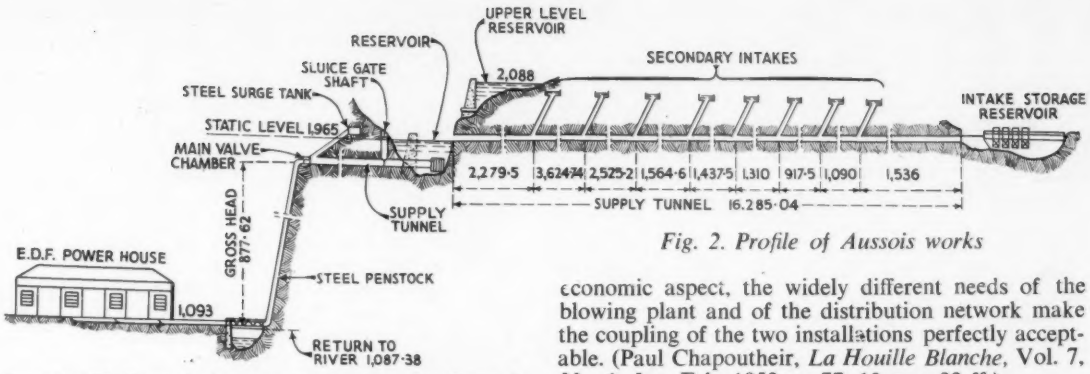


Fig. 2. Profile of Aussois works

length, 107.63 sq. ft. in cross section, starting from the Plan d'Aval reservoir and leading to the surge tank;

(f) a penstock consisting of pipes reinforced, in part, by rolled steel hoops, in part by slings made of steel ropes; total length about 2,000 yards, weight 1,900 tons, diameter 5.57 to 5.25 ft.;

(g) a power house (3,282 ft.) housing three 30,000 kVA turbo-alternators. Energy is transmitted to the line at 45 and 150 kV.

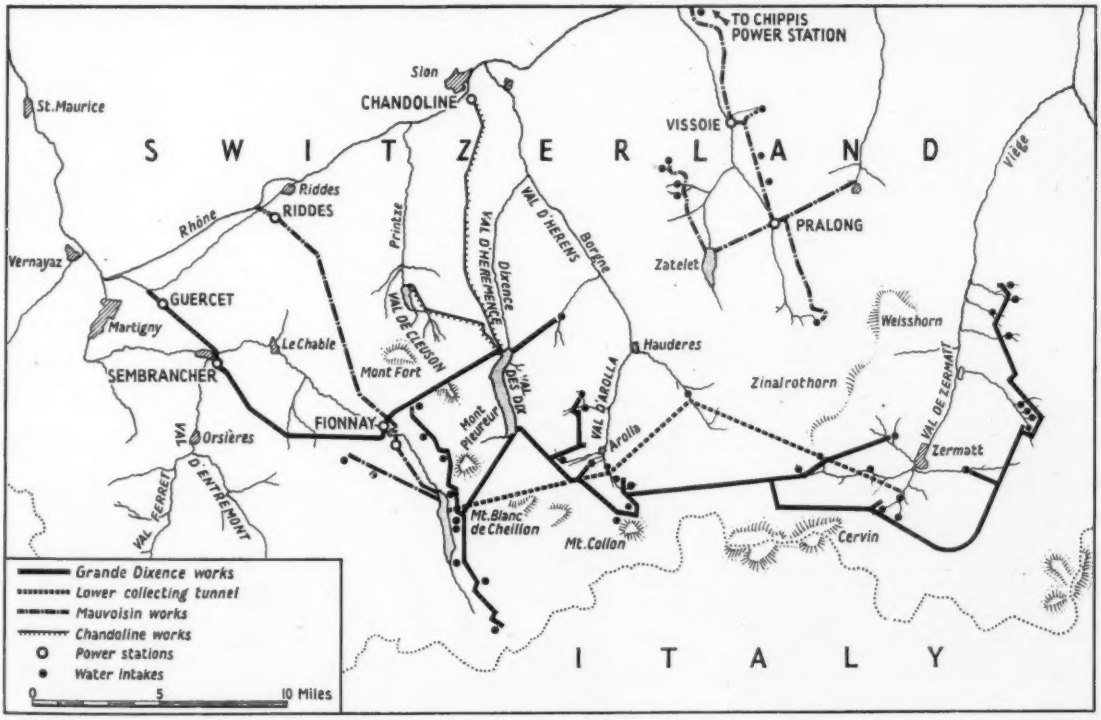
The penstock connects at its lower end with a pressure conduit which feeds, according to requirements, either the power house or the turbines actuating the blowing engines, or part of both at the same time. During short periods, never exceeding 10 minutes, the blowing plant calls for an input which may reach the whole of the water power available; otherwise, the blowing plant can adapt itself to a daily or yearly operating schedule which ensures an adequate supply of hydraulic power to the turbines of the power house. The setting up of the Plan d'Aval reservoir partly answers these requirements. Considered from the economic aspect, the widely different needs of the blowing plant and of the distribution network make the coupling of the two installations perfectly acceptable. (Paul Chapoutheir, *La Houille Blanche*, Vol. 7, No. 1, Jan.-Feb. 1952, p. 77, 10 pp., 22 ff.)

New Hydro-Electric Schemes in Switzerland

This is an account of a lecture delivered on March 18, 1952, by Professor A. Stucky, consulting engineer, and director of the Lausanne "Ecole Polytechnique," on new hydro-electric development in French-speaking Switzerland.

After a brief description of the Franco-Swiss Châtelot scheme,* the lecturer deals with the development of the southern area of the Rhone valley between Zermatt and Bagnes, which confronted the authors of the project with the following dilemma: To impound either 400 M cu. m. at 2,400 m. or 600 M cu. m. at 2,000 m., that is to say to lose either 200 M cu. m. of water or 400 m. of head. Fortunately there were two favourable possibilities of storage in the Val-des-Dix and Bagnes valley respectively, each permitting a reserve to be impounded varying between 200 and 400 M cu. m., according to the crest level

* WATER POWER, February 1952, p. 77.



of the dams. Professor Stucky shows how the combination of two main intakes at 2,400 and 2,000 m. with the two substantial storage possibilities available, enables the whole catchment area to be utilised while reducing water and head losses to a minimum. The two Mauvoisin and Grande-Dixence projects answer these requirements.

The Mauvoisin scheme has been reviewed in our issue of January 1952, p. 39, and we shall deal here with the Grande-Dixence only. A gravity dam 275 m. in height, involving the placing of 6 M cu. m. of concrete, will raise the level of the Grande Dixence lake in the Val-des-Dix 120 m. above the present level. In addition to the existing Chandoline power house, which will be kept in operation, this scheme comprises four new generating stations, one at the foot of the dam for reducing the pressure, the others in the Rhone valley at Fionnay, Sembrancher and Le Guerset. Inclusive of Chandoline the aggregate installed power will be 870,000 kW and the yearly energy output about 1,600 M kWh.

After giving a few particulars of the Gougra project, which will utilise the waters of the Tourtemagne, Anniviers and Moiry valleys at the Pralong, Vissoie and Chippis power plants and thus supplement the Mauvoisin and Grande-Dixence schemes, Professor Stucky wound up his lecture with a brief review of the problems involved in the construction of these large dams, such as the forecasting of dangerous floods according to the theory of probability, static tests on small models, control of dam deformation, and cooling of concrete following the temperature rise caused by the setting of great masses of concrete in a dam. (*Bulletin Technique de la Suisse Romande*, Vol. 78, No. 8, 19.4.52, p. 116, 2 pp., 1 f.)

Concrete Logs Seal Diversion Tunnel

The 1,300 ft. tunnel through which waters of North Santiam River (Oregon) have passed during the past two years of construction, was sealed by means of 14 reinforced mastic-coated concrete logs, each 30 ft. long and weighing 18 tons. Cranes located on an adjoining cliff lowered the logs into place, one on top of the other. The logs in place, the usual discharge of water was stopped, and the reservoir behind the dam took form. Within 24 hours water had risen more than 20 ft. to the first outlet valves through which the stream will flow during the summer. The valves will be closed this autumn and water will start filling a reservoir that will extend 9 miles upstream and hold 455 acre ft., the maximum depth being 400 ft. During late autumn and early winter the reservoir will be held at minimum flood control elevation to provide storage space for excess water during runoff periods.

Detroit Dam is a unit of the Corps of Engineers Willamette basin flow control and power project in western Oregon; its length is 1,580 ft., with a maximum height of 463 ft., and 1,500,000 cu. yards of concrete have been used in its construction. ("Engineering News-Record," Vol. 149, No. 6, Aug. 7, 1952, p. 53, 1 p., 3 ff.).

Steel-Cored Aluminium Conductors

The author of this article asserts, at the outset, that the steel core of aluminium conductors constitutes a superfluous load unless the aluminium conductor is submitted to overstresses and reaches the limit of its elasticity; he then deals with the important problem of the influence of temperature on the mechanical combination of an aluminium sheath with a steel core.

Considering the steel-cored aluminium conductor purely as the combination of an aluminium current carrier with a steel core acting as an overstress absorber, the correct ratio of the concentric cross-section of the aluminium sheath to the cross-section of the steel core is of the utmost importance if non-elastic elongations of the sheath are to be avoided.

After establishing that the increased resistance offered to overstresses can also be ensured by a non-cored aluminium conductor of mechanically equivalent cross-section, the author examines the advantages of a 1·25 times greater span, as secured with cored conductors, against the halved energy losses in non-cored conductors, and concludes in favour of the latter. (Milan Vidmar senr., Ljubljana, "Elektrotehniski Vestnik," Vol. 20, No. 5/6, June 1952, p. 117, 11 pp., 1 f.)

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Announcements for this column can be accepted up to the 8th of the month for the following month's issue. The charges are fourpence per word with a minimum of 10s. Box No. facilities 2s. 6d. extra. In order to avoid accountancy it would be appreciated if instructions to insert were accompanied with remittance.

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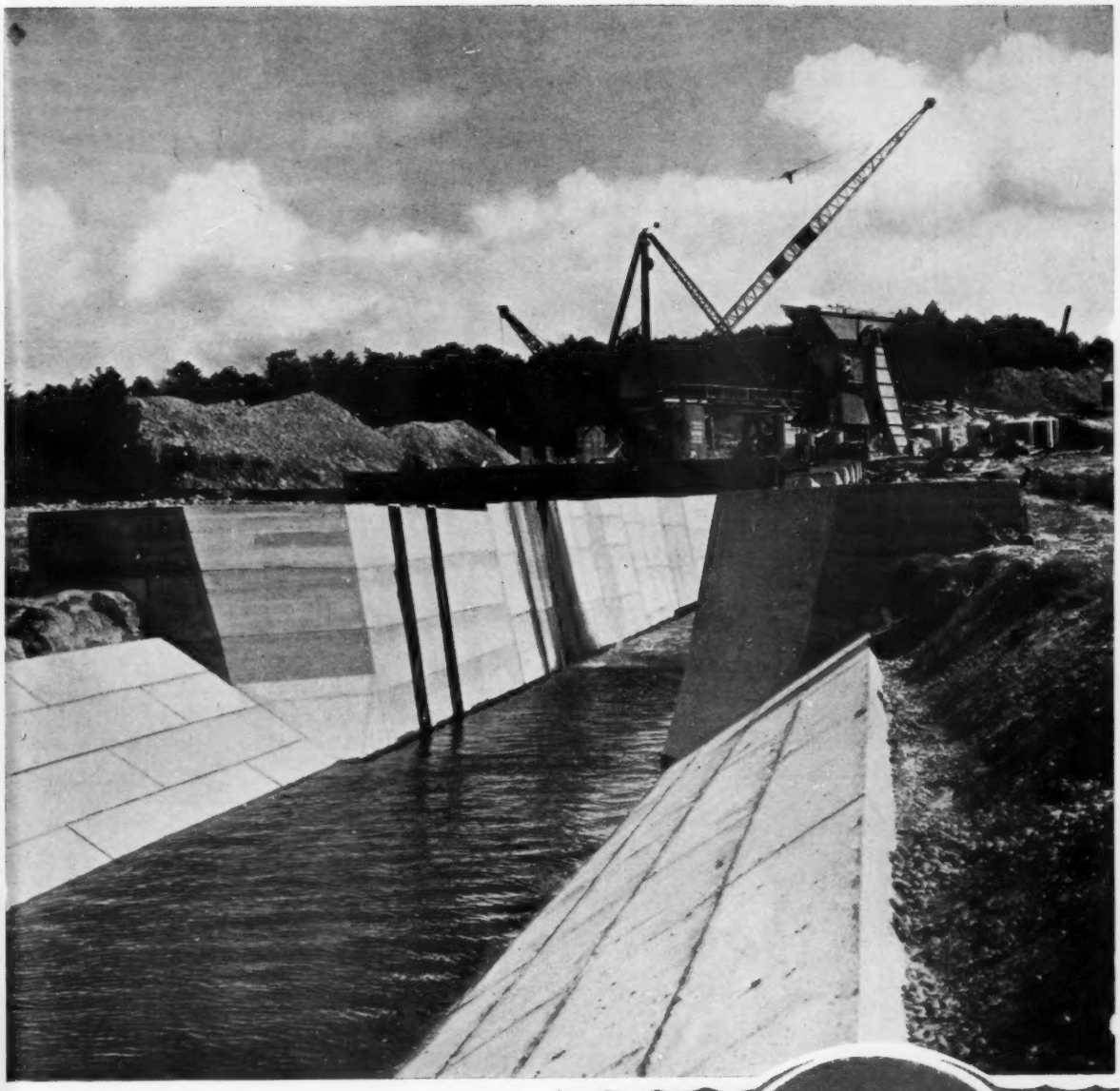

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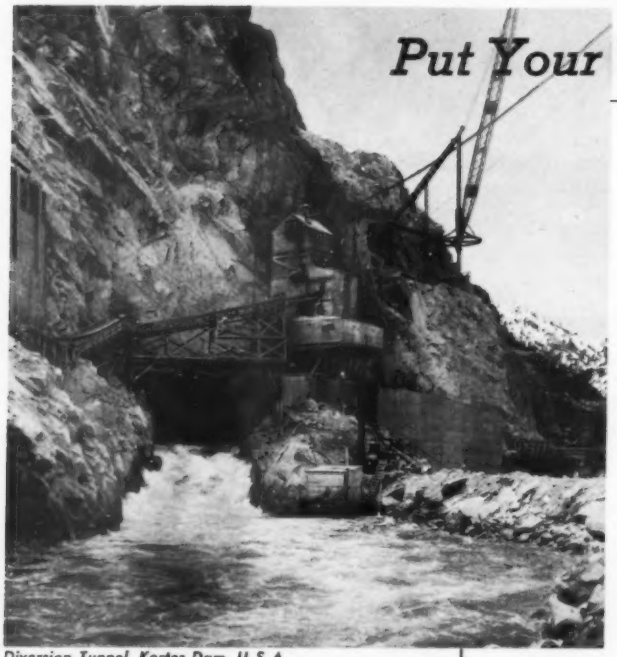

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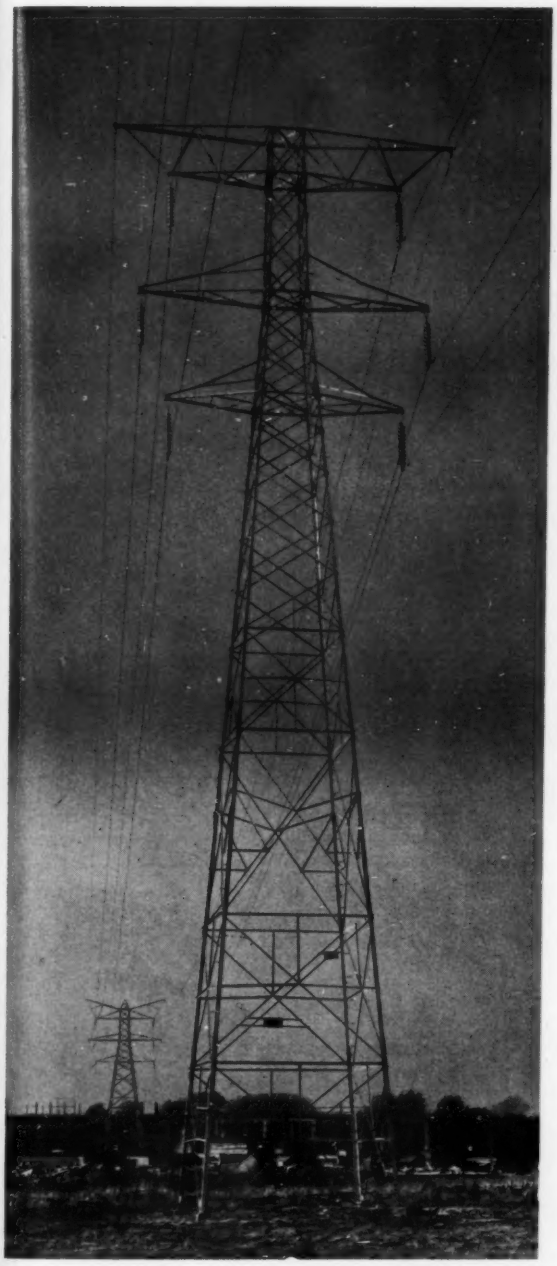

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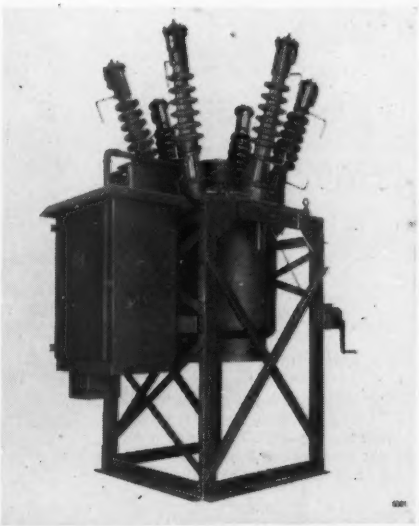

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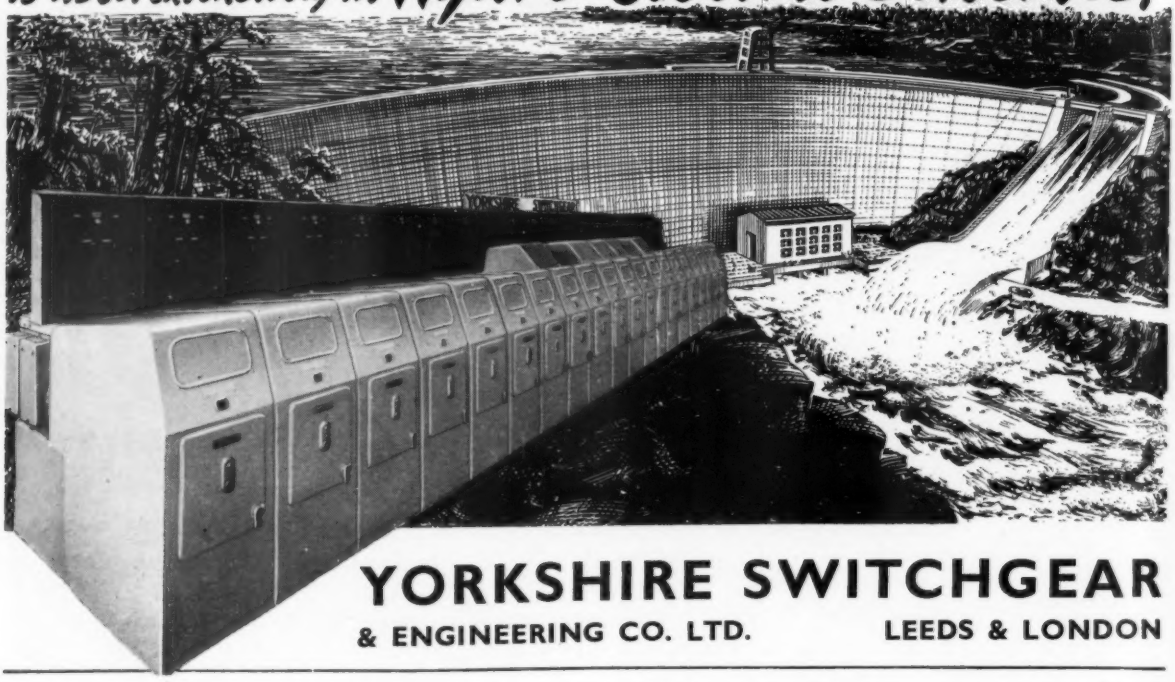

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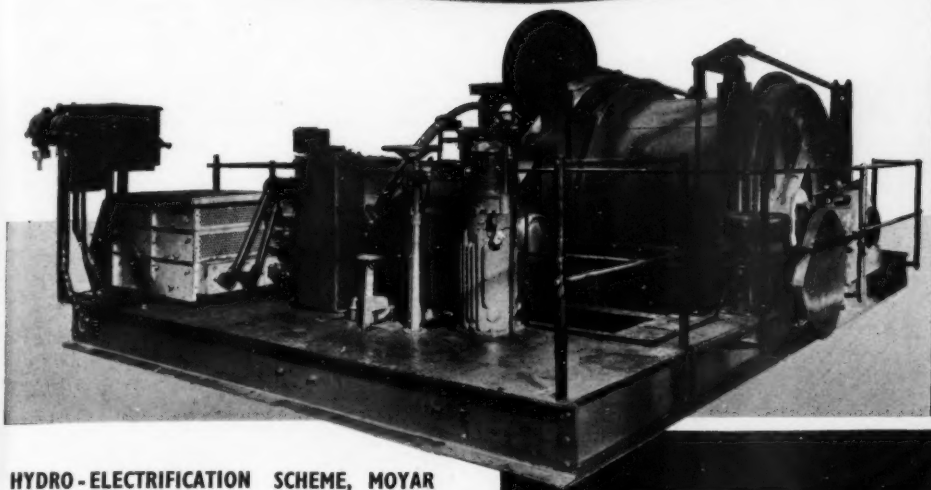

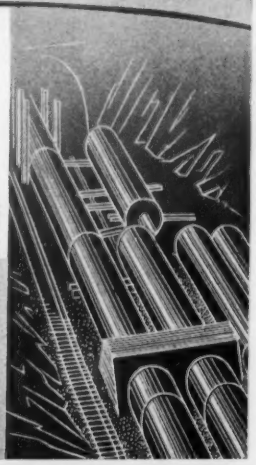

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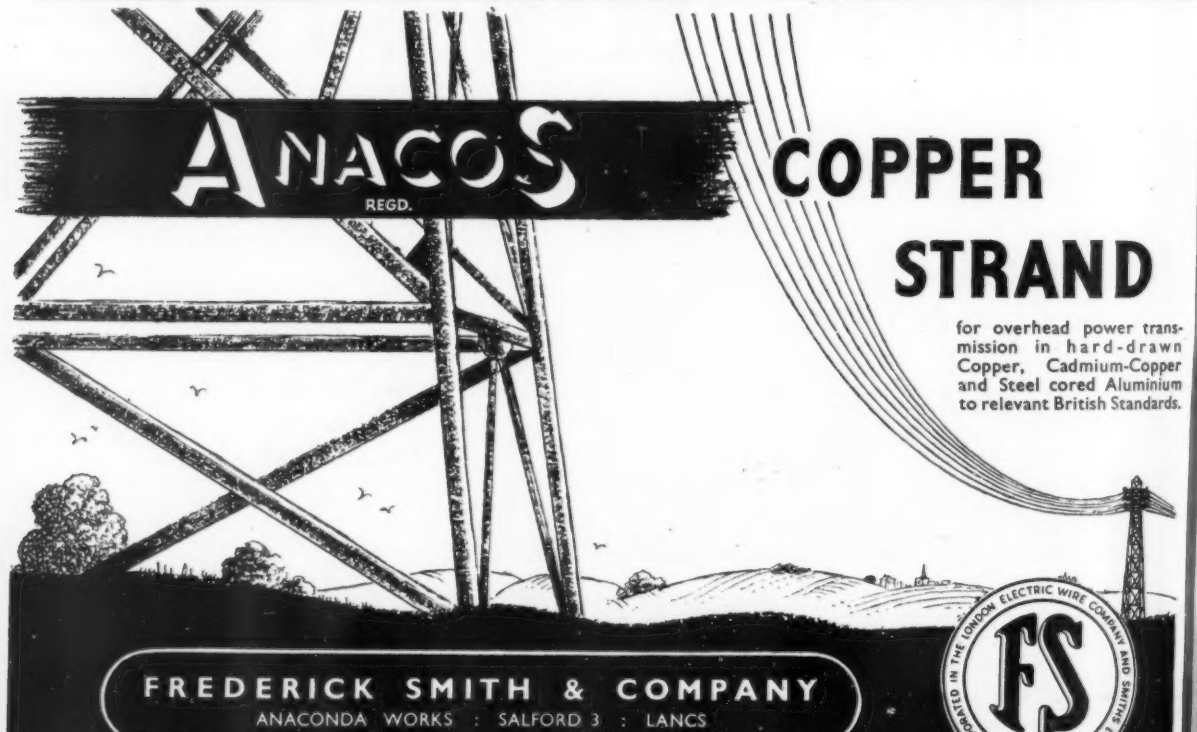
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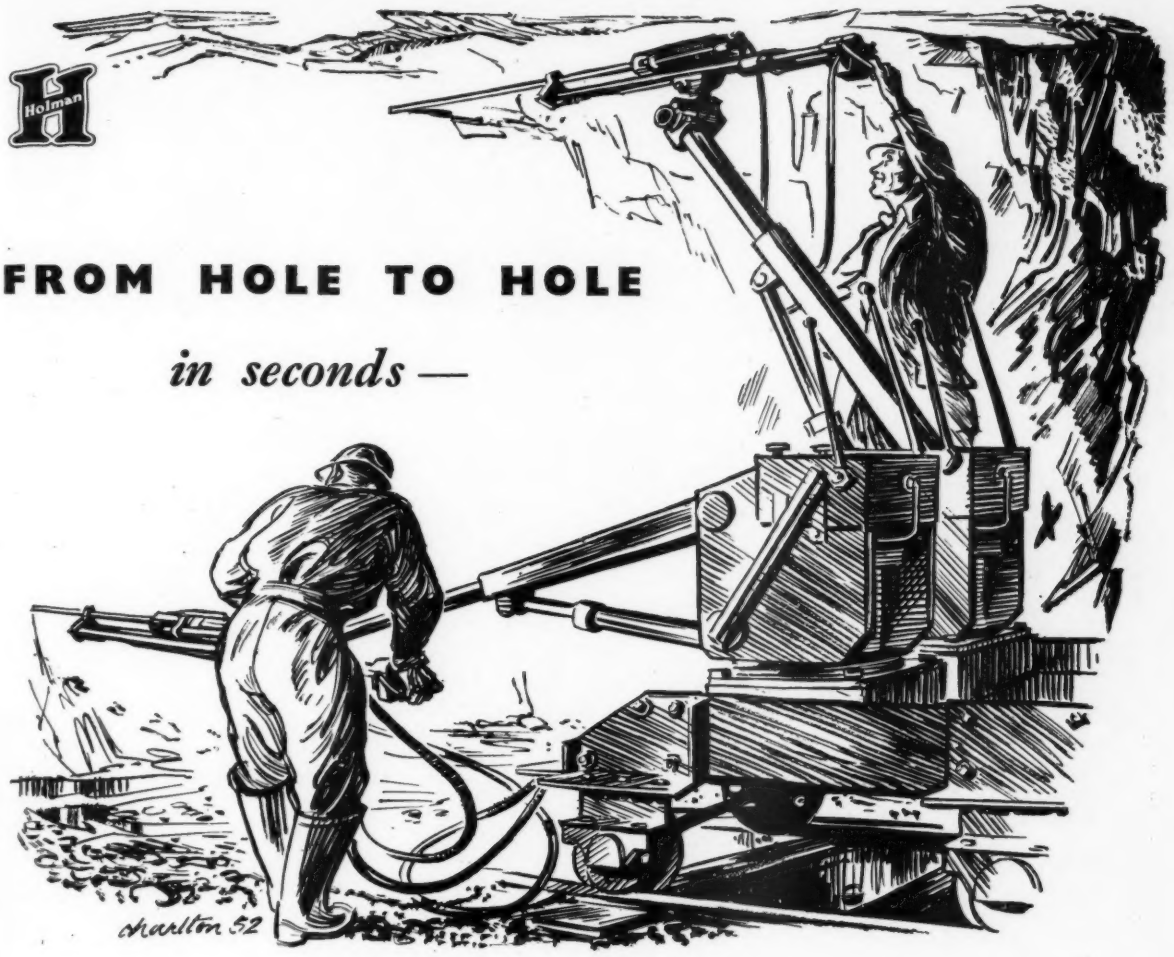

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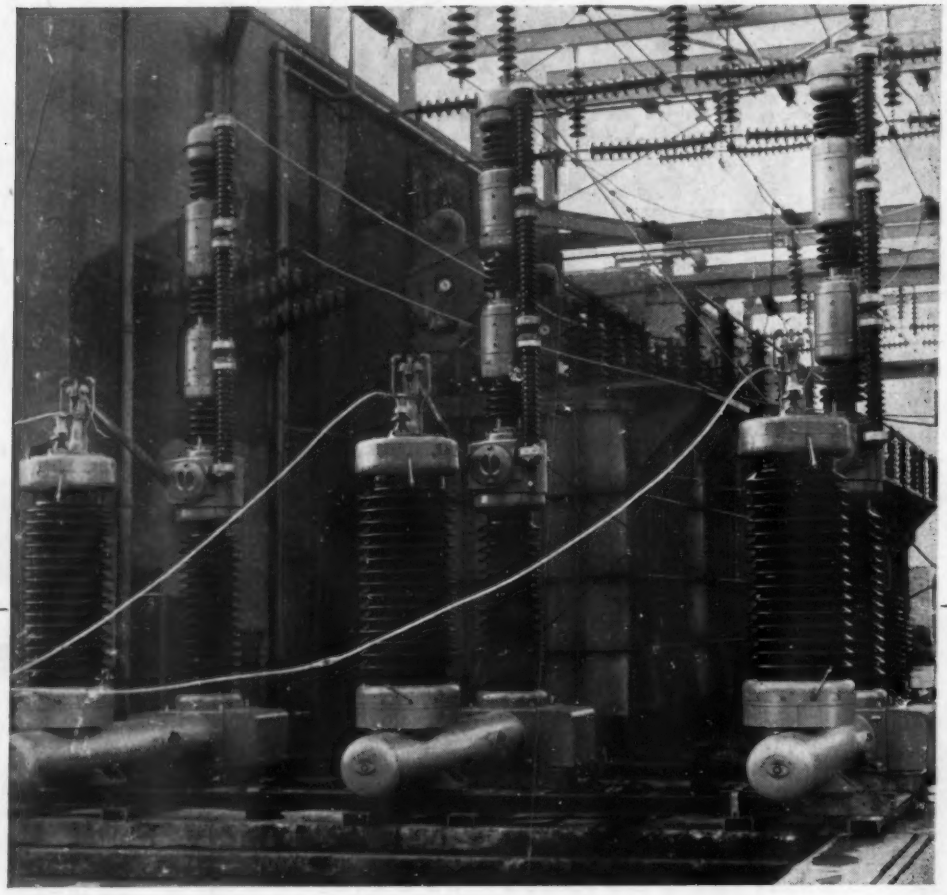

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